The Journal of Bone and Joint Surgery

The Official Publication of
The American Orthopaedic Association
The British Orthopaedic Association
The American Academy of Orthopaedic Surgeons
The Australian Orthopaedic Association
The Canadian Orthopaedic Association
American Society for Surgery of the Hand
New Zealand Orthopaedic Association
South African Orthopaedic Association

APRIL 1959

American Volume
Vol. 41-A, No. 3

8 THE FENWAY, BOSTON 15, MASSACHUSETTS, U. S. A.
BRITISH OFFICE:
82 PORTLAND PLACE, LONDON, W. 1, ENGLAND

The Journal of Bone and Joint Surgery

PUBLISHED IN TWO VOLUMES

WILLIAM A. ROOBER, *Editor-in-Chief Emeritus*

AMERICAN VOLUME

BRITISH VOLUME

Editor and Chairman Board of Editors: THORNTON BROWN

SIR REGINALD WATSON-JONES, *Editor*

American Board of Associate Editors

CHARLES O. BECHTOL, Los Angeles, California
WILLIAM H. BICKEL, Rochester, Minnesota
DAVID M. BOSWORTH, New York, N. Y.
CRAWFORD J. CAMPBELL, Albany, New York
JONATHAN COHEN, Boston, Massachusetts
ALBERT B. FERGUSON, JR., Pittsburgh, Pennsylvania
S. BENJAMIN FOWLER, Nashville, Tennessee
CHARLES H. FRANTZ, Grand Rapids, Michigan
J. LEONARD GOLDNER, Durham, North Carolina
DAVID S. GRICE, Philadelphia, Pennsylvania
GEORGE HAMMOND, Boston, Massachusetts
CHARLES H. HERNDON, Cleveland, Ohio
FLOYD H. JEROMIN, San Francisco, California
WILLIAM A. LEMON, Chicago, Illinois
LEO S. LUCAS, Portland, Oregon
MICHAEL L. MASON, Chicago, Illinois
JOHN H. MOE, Minneapolis, Minnesota
JOHN ROYAL MOORE, Philadelphia, Pennsylvania
JESSE T. NICHOLSON, Philadelphia, Pennsylvania
FRED C. REYNOLDS, St. Louis, Missouri
DANIEL C. RIORDAN, New Orleans, Louisiana
LEE RAMSAY STRAUB, New York, N. Y.
VERNON P. THOMPSON, North Hollywood, California

British Editorial Board

SIR WALTER MERCER, *Chairman*
H. JACKSON BURROWS, *Deputy Editor*
J. CRAWFORD ADAMS, *Assistant Editor*
PHILIP WILES, *Treasurer*
C. L. ALLEN, Cape Town, South Africa
ROLAND BARNES, Glasgow, Scotland
NORMAN CAPENER, Exeter, England
JOHN CHARNLEY, Manchester, England
W. D. COLTART, London, England
F. P. DEWAR, Toronto, Canada
J. KENNEDY ELLIOTT, Wellington, New Zealand
A. L. EYRE-BROOK, Bristol, England
T. J. FAIRBANK, Cambridge, England
ROGER GARIÉPY, Montreal, Canada
B. KEON-COHEN, Melbourne, Australia
H. ORMOND-CLARKE, London, England
DOUGLAS PARKER, Hobart, Tasmania
L. W. PLEWES, Luton, England
ROBERT ROAF, Oswestry, England
E. W. SOMERVILLE, Oxford, England
GORONWY THOMAS, Liverpool, England
J. TRUETA, Oxford, England

Corresponding Editors

Argentina: JOSÉ VALLS
Austria: WALTHER EHALT
Belgium: JEAN VERBRUGGE
Brazil: F. E. GODOY MOREIRA
Cuba: ALBERTO INCLÁN
Denmark: JOHANNES MORTENS
Finland: K. E. KALLIO
France: R. MERLE D'AUBIGNÉ
Germany: MATHIAS HACKENBROCH
Italy: O. SCAGLIETTI
Japan: EIICHI KONDO
Mexico: JUAN FARILL
Netherlands: J. D. MULDER
Poland: ADAM GRUCA
Portugal: ARNALDO RODO
Sweden: STEN FRIBERG
Uruguay: JOSÉ LUIS BADO

Committees

THE JOURNAL OF BONE AND JOINT SURGERY, INCORPORATED

The American Orthopaedic Association

The American Academy of Orthopaedic Surgeons

BOARD OF TRUSTEES

JAMES S. SPEED, *Chairman, pro tempore*
EDWARD L. COMPERE, *Secretary*
DAVID M. BOSWORTH, *Treasurer*
THORNTON BROWN, *Editor*
GUY A. CALDWELL
KERNE O. HALDEMAN
H. RELTON MCCARROLL

American Society for Surgery of the Hand
President: JULIAN M. BRUNER
President-Elect: DANIEL C. RIORDAN
Secretary-Treasurer: GEORGE S. PHALEN
2020 East 93rd Street, Cleveland 6, Ohio

The Australian Orthopaedic Association
JOHN LANE, Brisbane, *President*
WARWICK STENING, Sydney, *Editorial Secretary*
RICHARD HODGKINSON, *Secretary*, 135 Macquarie Street, Sydney, New South Wales

The British Orthopaedic Association
NORMAN CAPENER, *President*
E. W. SOMERVILLE, *Editorial Secretary*
J. CRAWFORD ADAMS, *Secretary*
45 Lincoln's Inn Fields, London, W.C. 2

The Canadian Orthopaedic Association
J. GORDON PETRIE, Montreal, *President*
J. PAUL ROOBER, Quebec, *Vice-President*
IAN W. DAVIDSON, *Secretary-Treasurer*
130 Elm Street, Sudbury, Ontario
W. B. MACKINNON, *Editorial Secretary*
661 Broadway, Winnipeg, Manitoba

New Zealand Orthopaedic Association
H. WALDEN FITZGERALD, Dunedin, *President*
ALLAN MACDONALD, Auckland, *Vice-President*
ALAN ALLRED, Dunedin, *Secretary-Treasurer*
N. NEBBT, *Editorial Secretary*
Dunedin Hospital, Dunedin, C.1, New Zealand

South African Orthopaedic Association
A. J. HELFET, *President*
SIDNEY SACKS, *Treasurer*
GEORGE DOMMISSE, *Secretary*
303 van Riebeek Medical Buildings, Pretoria, South Africa

Published in the United States by The Journal of Bone and Joint Surgery, Incorporated

Copyrighted in the United States by The Journal of Bone and Joint Surgery, Incorporated

Published in the United Kingdom for The British Editorial Society of Bone & Joint Surgery by E. & S. Livingstone, Teviot Place, Edinburgh

Copyright in Britain and the Commonwealth by The British Editorial Society of Bone & Joint Surgery

THE JOURNAL OF BONE AND JOINT SURGERY

American Office

8 The Fenway, Boston 15, Massachusetts, U.S.A.
Managing Editor: John A. Reed
Assistant Editor: H. Stephen Tilton

British Office

82 Portland Place, London, W. 1, England
Editorial Secretary: Jean Barnes

The Journal of Bone and Joint Surgery*

American Volume

TABLE OF CONTENTS

April 1959

PAGE

Metabolic Studies in Orthopaedic Patients.
By *George E. Spencer, Jr., M.D., Harvey Krieger, M.D., William E. Abbott, M.D.,* and *Stanley Levey, Ph.D.*, Cleveland, Ohio 381

Posterolateral Bone-Grafting for Fusion of the Lumbar and Lumbosacral Spine.
By *Melvin Brent Watkins, M.D.*, New York, N. Y. 388

Léri's Pleonosteosis. A Study of a Family with a Review of the Literature.
By *John G. Rukavina, M.D., Harold F. Falls, M.D., John F. Holt, M.D.*, and *Walter G. Block, Ph.D.*, Ann Arbor, Michigan 397

Bone-Graft Operations to Lengthen the Humerus in Short Arm Amputation Stumps. Report of the Results in Two Bilateral Above-the-Elbow Amputees.
By *Marshall R. Urist, M.D.*, and *Robert Mazet, Jr., M.D.*, Los Angeles, California ... 409

The Use of a Bilateral Canadian-Type Hip-Disarticulation Prosthesis for Congenital Absence of Both Lower Extremities.
By *Cline D. Hensley, Jr., M.D.*, Wichita, Kansas 417

Femoral Torsion and Its Relation to Toeing-In and Toeing-Out.
By *Lawrence Crane, M.D.*, Portland, Maine 421

Capsular Arthroplasty in Paralytic Dislocation of the Hip. A Preliminary Report.
By *S. L. Weissman, M.D.*, Tel-Aviv, Israel 429

Prevention of Acquired Dislocation of the Hip in Cerebral Palsy.
By *Winthrop M. Phelps, M.D.*, Baltimore, Maryland 440

Chronic Neurological Sequelae of Acute Trauma to the Spine and Spinal Cord. Part II. The Syndrome of Chronic Anterior Spinal Cord Injury or Compression. Herniated Intervertebral Discs.
By *Richard C. Schneider, M.D.*, Ann Arbor, Michigan 449

Chronic Neurological Sequelae of Acute Trauma to the Spine and Spinal Cord. Part IV. Problems Pertaining to the Treatment of Retained Foreign Bodies.
By *Richard C. Schneider, M.D.*, and *Edgar A. Kahn, M.D.*, Ann Arbor Michigan 457

(Continued on page 3)

The Journal of Bone and Joint Surgery (American Volume) is issued eight times a year—in January, March, April, June, July, September, October, and December. The 1959 subscription price, payable in advance, is $14.50. Single copies $3.00.

The Journal of Bone and Joint Surgery, second-class postage paid at Boston, Mass. and at additional mailing offices. Editorial and business offices, 8 The Fenway, Boston, Mass. Accepted at the special rate of postage provided for in the act of February 28, 1925. Paragraph 4, Section 412, Postal Laws and Regulations; authorized April 21, 1932. Additional entry at Concord, New Hampshire, authorized June 10, 1947.

Copyright 1959 by *The Journal of Bone and Joint Surgery, Incorporated*

*TITLE REGISTERED IN UNITED STATES PATENT OFFICE

The Journal of Bone and Joint Surgery WELCOMES ARTICLES WHICH CONTRIBUTE TO SURGICAL SCIENCE FROM ALL COUNTRIES OF THE WORLD

Manuscripts submitted for publication in the AMERICAN VOLUME should be sent to The Editor, *The Journal of Bone and Joint Surgery*, 8 The Fenway, Boston 15, Massachusetts.
Manuscripts submitted for publication in the BRITISH VOLUME should be sent to The Editor, *The Journal of Bone and Joint Surgery*, 82 Portland Place, London, W. 1, England.

INFORMATION FOR CONTRIBUTORS TO THE AMERICAN VOLUME

- Articles are accepted only for exclusive publication in *The Journal of Bone and Joint Surgery*.
- Publication does not constitute official endorsement of opinions presented in articles.
- Articles published and their illustrations become the property of *The Journal*.

Careful attention to the following suggestions can save much time and correspondence.

WHEN YOU SUBMIT AN ARTICLE PLEASE SEND:

1. THE ORIGINAL MANUSCRIPT. Keep a copy. The original manuscript of an accepted article will not be returned. Several editors report on every manuscript. One or two extra copies with illustrations sent to us will accelerate this procedure.
2. BIBLIOGRAPHY, alphabetical, of references made in text *only*. Please refer to bibliographies in this copy of *The Journal* and follow style exactly.
3. LEGENDS for all illustrations submitted, listed in order.
4. ILLUSTRATIONS
   a. *Black and white glossy prints* of photographs.
   b. *Direct-contact glossy prints* from the original roentgenograms, not prints from secondary negatives.
   c. *Original* drawings or charts.
   d. *Magnification* of photomicrographs.

NOTES ON PREPARATION OF MANUSCRIPT

- Manuscripts must be typewritten, double-spaced with wide margins.
- Write out figures under 100 except percentages, degrees, or figures expressed in decimals.
- Direct quotations should include exact page numbers on which quotation appeared in book or article.

NOTES ON PREPARATION OF ILLUSTRATIONS

- Number all illustrations.
- Indicate *top* plainly.
- Write author's name on the back of each one.
- Put dates or initials in *Legends*, not on prints.
- Send prints unmounted or mounted only with rubber cement. Paste or glue will damage prints.
- Drawings, charts, and lettering on prints should be done with black India ink. Use white India ink on black backgrounds.
- Make lettering large enough to be read when drawings are reduced.
- When submitting an illustration which has appeared elsewhere give full information about previous publication, credit to be given, and state whether or not permission to reproduce has been obtained.

COPYRIGHT

Material appearing in *The Journal* is covered by copyright. As a general rule permission will be given to reputable medical journals to reprint anything in these pages, if permission is first obtained from *The Journal* and if the material used is properly credited to *The Journal*.

FOR ADDITIONAL INFORMATION, PLEASE WRITE TO THE EDITOR

TABLE OF CONTENTS

(Continued from page 1)

PAGE

The Effect of Total Body Irradiation on Bone Transplants in Parabiosed Animals. By *William F. Enneking, M.D.*, Jackson, Mississippi, and *Avrum Gratch, B.Sc.*, Chicago, Illinois 463

Congenital Posterior Angulation of the Tibia with Talipes Calcaneus. A Long-Term Report of Eleven Patients. By *Clarence H. Heyman, M.D., Charles H. Herndon, M.D.*, and *Kingsbury G. Heiple, M.D.*, Cleveland, Ohio 476

Dislocations of the Shoulder with Special Reference to Accompanying Small Fractures. By *Richard H. Hall, M.D., Frank Isaac, M.D.*, and *Charles R. Booth, M.D.*, Long Beach, California. 489

Epiphyseal Growth Arrest in a Fractured Metacarpal. By *Joseph Edmund Brown, M.D.*, Cleveland, Ohio 494

Partial and Complete Agenesis or Malformation of the Sacrum with Associated Anomalies. Etiologic and Clinical Study with Special Reference to Heredity. A Preliminary Report. By *Johanna Blumel, Ph.D., E. Burke Evans, M.D.*, and *G. W. N. Eggers, M.D.*, Galveston, Texas 497

Reconstruction of a Digit Following Loss of All Fingers with Preservation of the Thumb. By *G. N. Lassar, M.D.*, St. Louis, Missouri 519

Corrosion in a Device for Fracture Fixation. By *Jonathan Cohen, M.D.*, and *George Hammond, M.D.*, Boston Massachusetts 524

A Radioisotopic Investigation of the Contamination of Screws and Tissues by Screwdrivers. A Study in Applied Metallurgy. By *P. G. Laing, M.B., F.R.C.S., Laverne R. Madancy, B.S.*, and *Mary A. Grebner, B. A.*, Pittsburgh, Pennsylvania 535

Unexpected Roads to Greatness. [Presidential Address: The American Academy of Orthopaedic Surgeons, 1959.] By *H. Relton McCarroll, M.D.*, St. Louis, Missouri 546

Proceedings:
Western Orthopedic Association 553
Congress of the Sociedade Brasileira de Ortopedia e Traumatologia 569

New Notes 571

Book Reviews 574

List of Advertisers ..... Adv. 68

Addresses of Contributors ..... Adv. 70

Subscription Rates for 1959

American Volume, $14.50
Published January, March, April, June, July, September, October, December

British Volume, $7.50
Published February, May, August, November

All subscription rates include postage.

Checks should be made payable to *The Journal of Bone and Joint Surgery, Inc.*

Microfilms of the American Volumes are available to regular subscribers through University Microfilms, 313 North First Street, Ann Arbor, Michigan

THE JOURNAL OF BONE AND JOINT SURGERY

American Office
8 The Fenway, Boston 15, Massachusetts, U. S. A.

British Office
82 Portland Place, London, W. 1, England

Only CURITY has the two finest plaster bandages . . . to give you

the right cast for every fracture case

OSTIC®

all-around high utility

Strong, fast and precise, this is the everyday, easy-to-use bandage. It delivers at least 97% of the original plaster to the cast because of the inseparable bonding of plaster and starch-free crinoline. Available in two settings of Fast (5 to 9 min.) and Extra-Fast (2 to 5 min.).

Ostic bandages stand up under all kinds of wear, even with those rambunctious little patients. It is also known for being consistent. Every time you open that waterproof package, you know you're going to get the same good results you had with the last one.

For strength and all-around, everyday use—OSTIC.

Gypsona*

creamy extra quality

Shiny and pure, made from finely ground plaster from a quarry in England, Gypsona plaster bandages not only perform all the functions expected of a plaster bandage, but also have certain exceptional qualities.

There's the interlocked, woven fabric that provides exceptional conformability around bones, protuberances—even indentations. (Setting time 4 to 5 min.). Then, Gypsona has an extraordinary combination of lightweight mobility and iron-like durability. And you get a gleaming, snow-white finish. Every time.

True, you pay a little more for Gypsona. But it gives you an uncommonly broad versatility in plaster.

Ostic and Gypsona come in individual airtight packages which prevent pre-setting. Plaster stays fresh indefinitely.

FREE BOOK—*"Gypsona Technique", textbook of modern plaster methods, 140 illustrations. Write Bauer & Black—309 W. Jackson Blvd., Chicago 6, Ill.*

Curity®

PLASTER BANDAGES

Bauer & Black

DIVISION OF THE KENDALL COMPANY

*Reg. T.M. of T.J. Smith & Nephew Ltd.

In answering advertisements, please mention *The Journal of Bone and Joint Surgery*.

Betadine®

BRAND OF POVIDONE-IODINE

UNSURPASSED BROAD-RANGE GERMICIDAL SPRAY

...confirmed in 100 surgical "prepping" procedures[1]

"The area was wiped dry (after the usual shave, wash, etc.) and povidone-iodine [BETADINE] sprayed over an adequate surface. Bacteriological cultures taken from the sites before and after operation indicated that all pathogens were eliminated by this procedure, the only remaining organisms being saprophytes and diptheroids."

...confirmed in 200 emergency suture cases[1]

"The wounds were cleansed of all foreign material, debrided and sprayed with povidone-iodine [BETADINE] prior to suture...All wounds healed *per primam* without side reactions or evidence of local irritation."

TOPICALLY APPLIED

Betadine

KILLS OUTRIGHT

pathogenic bacteria
viruses
fungi
protozoa
yeasts

- *prolonged release of effective germicidal action ...will not lead to the development of resistant strains*
- *unique film-forming property protects against invading pathogens...effective against Staph. aureus and other organisms resistant to topical antibiotics*
- *virtually non-irritating to skin and mucosa*

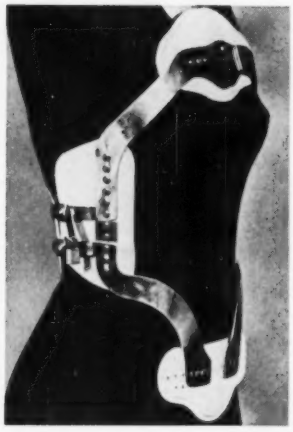
1. Garnes, A. L.; Davidson, E.; Taylor, L. E.; Felix, A. J.; Shidlovsky, B. A., and Prigot, A.: Clinical Evaluation of Povidone-Iodine Aerosol Spray in Surgical Practice, Am. J. Surg., 97:49 1959.

Available: BETADINE Aerosol in 3-oz. bottles.
BETADINE Antiseptic Solution in 8 and 16-oz. bottles.
More detailed information upon request.

TAILBY-NASON COMPANY, INC. DOVER, DELAWARE

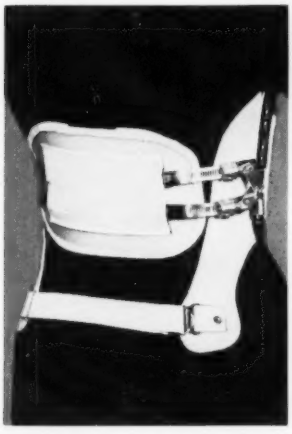
established in 1905

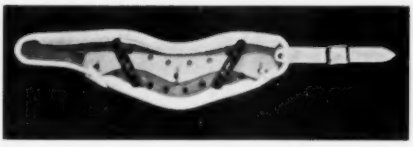
THE JEWETT HYPEREXTENSION BACK BRACE



This brace has proven its worth as a satisfactory hyperextension immobilization device in cases of uncomplicated compression fracture of the lower thoracic and entire lumbar spine. It maintains desired hyperextension as well or better than the best applied hyperextension plaster of paris cast. The brace weighs only a fraction of the weight of a cast, permits desired body hygiene and usually can be worn beneath ordinary garments with little or no alteration. Another advantage of the brace is its adjustability without loss of its hyperextension qualities.

SPINAL FUSION MODEL—The spinal fusion model has additional advantages which make it an admirable post-lower fusion brace where minimal motion in the fused area is desired.

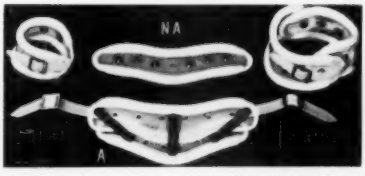




MYO-CERVICAL COLLAR

For cases such as whip-lash injuries, wry neck torticollis, etc.; adjustable as to height and degree of extension. Lower perimeter adjusts automatically to contour of sternum and clavical. Light, cool, comfortable and washable; provides positive support. Available in small, small-special, medium and large sizes.

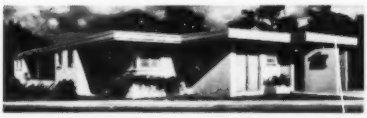
Literature, reprints and measuring charts upon request or better still, the name and address of our nearest bracemaker-distributor.



EXTENSION-FLEXION COLLAR

The Universal Cervical Collar

Indicated in those conditions requiring positive support and immobilization such as whip-lash injuries, wry neck and torticollis; also as an adjunct to braces or plaster casts in certain other post-traumatic and post-operative cervical lesions; This reversible collar may be used to maintain *extension, flexion* or *stabilization*, is semi-rigid, ventilated, completely cushioned and adjustable to height, circumference and degree of extension or flexion. All parts are interchangeable and washable. Available in small, medium and large sizes with interchanging of parts to make possible eighteen various sizes by use of double buckle straps.



FLORIDA BRACE CORPORATION

Post Office Box 1366 Winter Park 3, Florida

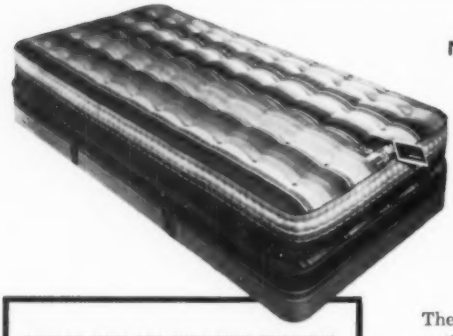
Phone MIdway 4-2650

In answering advertisements, please mention *The Journal of Bone and Joint Surgery*.

NO MORE

because VITAGENIC

THE PRESCRIPTION-BUILT **EXTRA-FIRM MATTRESS**



CURLED HAIR FOR RESILIENT FIRMNESS
Firm body support without undue pressure on nerve points or interference with circulation.

HAND-STITCHED SAG-FREE SIDEWALLS
Sag-free edges allow patients with back injuries to get in and out of bed with less effort and greater stability. 12% more usable sleeping area.

NEEDS NO "MAKESHIFT" INTERPOSED BOARD

Physicians and orthopaedic specialists know that a bedboard—even one that is interposed in a mattress—is only an attempt to correct a structural weakness and inadequacy in the mattress itself. The VITAGENIC by AIRE-LOOM requires no "make-shift" additions.

The VITAGENIC is a mattress and box spring combination made according to the exact specifications of registered orthopaedic specialists. It is an important—almost essential—adjunct to your plan of treatment for pain of backache or sacroiliac injury. You prescribe the exact degree of firmness necessary for your patient as well as any other features required for treatment or comfort.

THE VITAGENIC IS GUARANTEED FOR 15 YEARS.

Aireloom

For full details on the prescription-built VITAGENIC, contact:

BEDDING CO. • 1119 Westminster Ave., Alhambra, Calif.

created by King Karpen—established 1951

"It is axiomatic that prosthetic material for use within the body must be inert."[1]

The totality of clinical inertness

"...the surgeon should know as much about the material he puts into his patients as he does about the disease he is treating."[2]

Recently, Burch cogently summarized the criteria for metal appliances; he considers it most desirable that the appliance "be electrically neutral and entirely passive in the presence of body fluids, and sufficiently rigid and strong to do its part mechanically. It should retain its molecular veil of passivity in the presence of agitation and friction, and remain completely passive *in vivo*."[2]

ELECTRIC NEUTRALITY – In a discussion of metals in orthopedic surgery, McKee[3] emphasizes that even polishing or machining, as used in the production of stainless steel appliances, creates an electric potential, thus initiating a corrosive process. Such processes can also be triggered by damaging the investive oxide film and by mechanical stresses.[1-9]

VITALLIUM

VITA

In 1947 it was stated:

"Vitallium appliances can be left in the body indefinitely for... there is no damage to tissues, and there is no disintegration or solution of the metal in body fluid. As a result, appliances of Vitallium become embedded in bone and soft tissue with a minimum of scar tissue formation."[9]

References: 1. McKeever, D. C.: Clin. Orthop., No. 6, p. 17, 1955. 2. Burch, J. E.: Southern M. J. *51*:1390, Nov. 1958. 3. McKee, G. K.: Lancet *1*:1174, June 8, 1957. 4. Wright, J. K. and Axon, H. J.: J. Bone & Joint Surg. *38*B:745, Aug. 1956. 5. Scales, J. T. and Zarek, J. M.: J. Bone & Joint Surg. *37*B:527, Nov. 1955. 6. Callahan, J. J.: S. Clin. North America, W. B. Saunders Co., Philadelphia, Feb. 1957, p. 135. 7. Curry, G. J. and Pine, D. K.: Am. J. Surg. *95*:518, Apr. 1958. 8. Scales, J. T.: J. Bone

BODY FLUIDS AND METAL – As shown by Gross and Gold,[10] Vitallium implants – either cast or wrought – "were compatible with the soft tissues and bone and did not cause any observable clinical or histologic injury." Similar observations were made by Secord and Breck,[11] Smyth,[12] Venable and Stuck,[9] Wright and Axon[4] and others.[5,8] It was demonstrated[4] that plasma and normal saline not only affect stainless steel per se, but also accelerate electrolytic processes and corrosion. This "electrolytic inflammation" interferes with healing, and the tissue reaction or "chemical abscess," "may point through the skin and become secondarily infected." When using stainless steel, they frequently obtained "primary skin healing of the plated fracture without any evidence of sepsis, but with localized wound breakdown six or eight weeks later."[4]

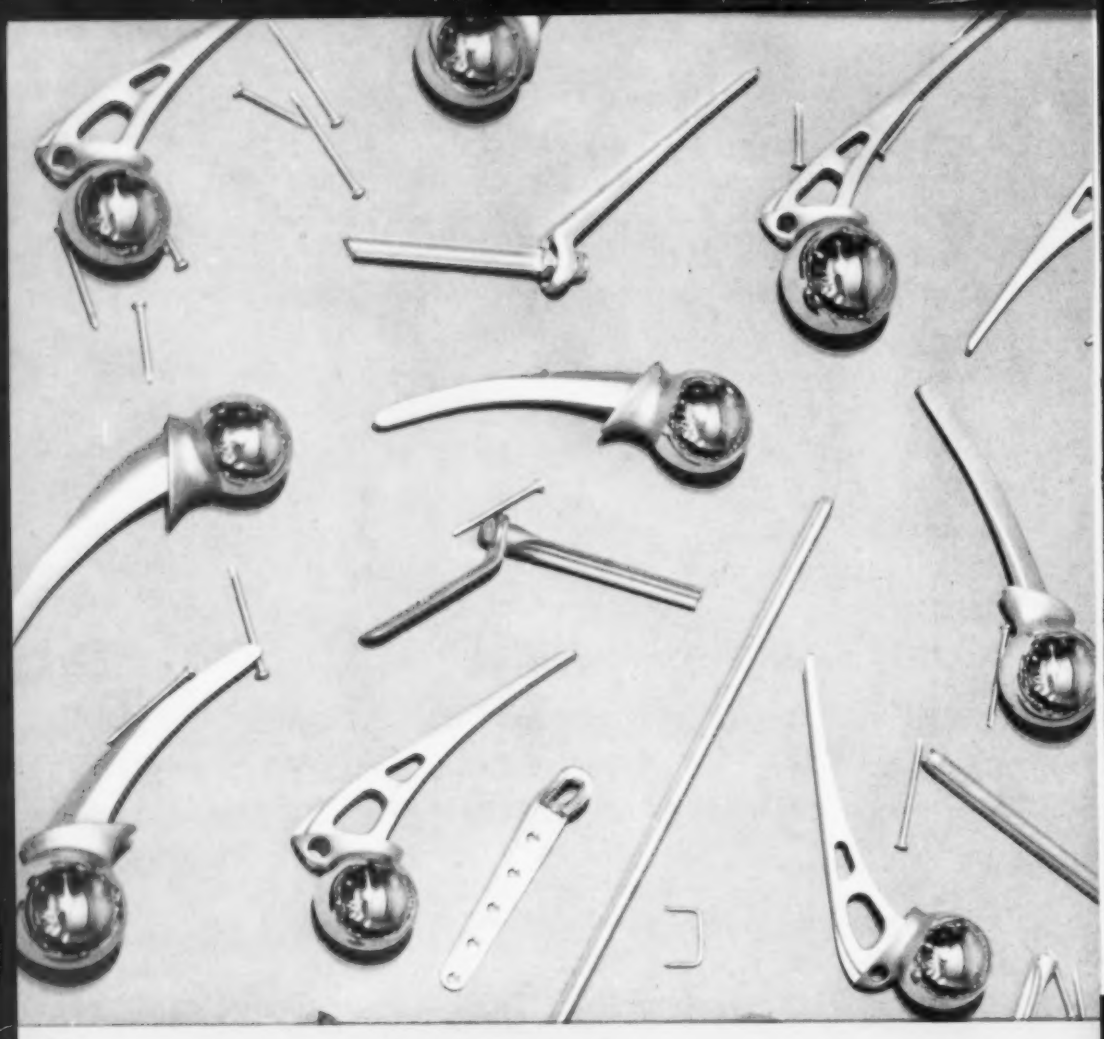
MECHANICAL STRENGTH – Day and Hinchey[13] report "no instances of fracture of the [Moore] prosthesis" and Scales and Zarek[5] "have never seen a cobalt-chrome implant which has failed either mechanically or biologically because of corrosion phenomena." They "believe that the cobalt-chrome alloys have in clinical experience proved to be so superior in all respects to the existing stainless steels that they should now be very seriously considered for all surgical implants."[5]

LLIUM

in 1957 it was reported:

"There is general agreement that Vitallium is the least physiologically disturbing [metal] to tissues . . . [Its] unique suitability for surgical appliances derives from its inherent corrosive resistance, its compatibility with human tissues, its inertness and lack of electrolytic activity, together with its toughness and strength."[6]

& Joint Surg. *38B*:754, Aug. 1956. **9.** Venable, C. S. and Stuck, W. G.: Internal Fixation of Fractures, Charles C. Thomas, Springfield, 1947, pp. 42-52, 63. **10.** Gross, P. P. and Gold, L.: Oral Surg. *10*:769, July 1957. **11.** Secord, E. W. and Breck, L. W.: J. Bone & Joint Surg. 22A:749, July 1940. **12.** Smyth, E. H. J.: J. Bone & Joint Surg. *40B*:778, Nov. 1958. **13.** Day, P. L. and Hinchey, J. J.: Clin. Orthop. No. 6, p. 27, 1955.



VITALLIUM

acceptance by surgeons is attested to by
the fact that over 7,500,000 Vitallium appliances
were used in the last 23 years...

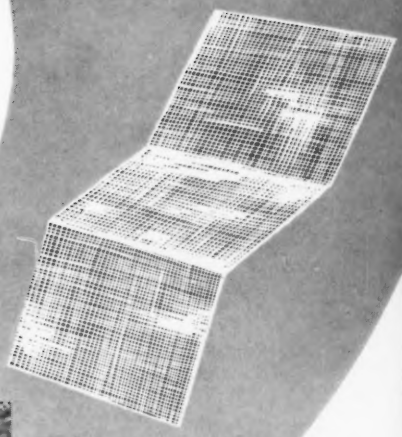
...that is over 900 daily!
the Alloy of Surgical Excellence

AUSTENAL, INC. *Surgical* DIVISION

224 EAST 39TH STREET · NEW YORK 16, N. Y.

AU11661

The NEW DUAL PURPOSE



VASELINE
PETROLATUM GAUZE U. S. P.
STERILE
3 x 3 PAD, opens to 3 x 9 INCHES
Fine Mesh Absorbent Gauze (44/36)
Impregnated with White Petrolatum
CHESEBROUGH-POND'S INC.
NEW YORK 17, N.Y.
UNOPENED ENVELOPE MAY BE AUTOCLAVED OR COLD-SOAKED
TEAR HERE

3″ x 9″ STRIP

Shorter length ends waste on small area wounds. New Z-fold insures perfect graft takes. Guaranteed sterile at time of use.

3″ x 3″ PAD

Three-ply, fine-mesh gauze, lightly impregnated — for use in physician's office, industrial medical department, first aid.

6th SIZE of VASELINE® PETROLATUM GAUZE

Now supplied in.

1/2″ x 72″	3″ x 18″
1″ x 36″	3″ x 36″
3″ x 3″ / 3″ x 9″	6″ x 36″

Sole Maker:

CHESEBROUGH-POND'S INC.
Professional Products Division
New York 17, N. Y.

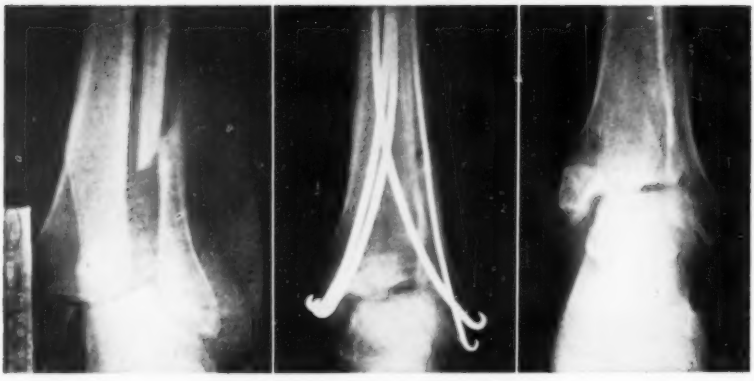
VASELINE *is a registered trademark of Chesebrough-Pond's Inc.*

Lock the Bone with Dynamics

SUMMARY OF BASIC TECHNICS*

The RUSH® MEDULLARY PIN

PAT. NO. 2,579,988



COMPLEX ANKLE FRACTURE

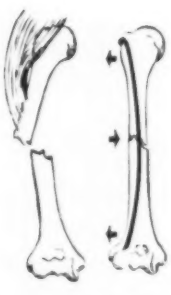
The pins here were straight when driven. Curves were produced by intraosseous pressures to give stable fixation without need for external splinting.

SINGLE PIN

Indicated when both fragments have substantial length.

STRAIGHT PIN: Areas indicated in black.

CURVED PIN: Shafts of humerus, femur and tibia. Resists muscle angulating force by three point pressure.



Humerus Shaft

Femur Shaft

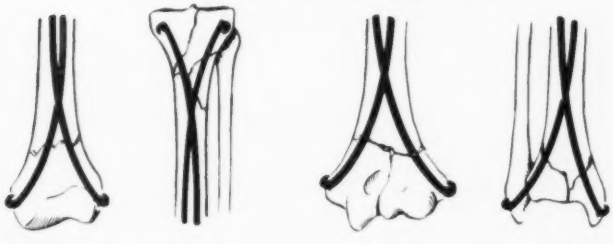
Tibia Shaft

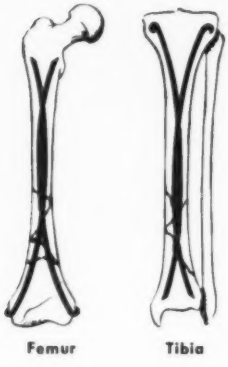
* Rush, Leslie V.: Fracture Problems, Mississippi Doctor, Vol. 36, No. 5:115–118, Oct., 1958.

In answering advertisements, please mention *The Journal of Bone and Joint Surgery*.

DOUBLE PINS

SIMILAR ANATOMIC AREAS

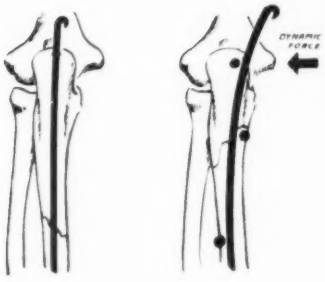


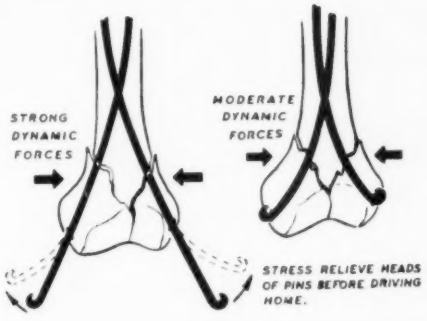


COMMINUTED FRACTURES

Similar Problems: Closed pinning best. Relatively good bone length can be maintained.

STRESS RELIEF OF HEADS





Pin inserted through end of bone exerts no dynamic force. Stress relief not necessary.

Pin inserted thrcugh side of bone is forced into curve. Result: Strong dynamic force with three point pressure. Head of pin can sink into bone unless stress relieved.

WRITE FOR INFORMATION
Exclusive Manufacturers of
RUSH MEDULLARY PINS AND INSTRUMENTS
Publishers of
"ATLAS OF RUSH PIN TECHNICS"
by LESLIE V. RUSH, M. D.

THE BERIVON *Company*
MERIDIAN, MISS.

In answering advertisements, please mention *The Journal of Bone and Joint Surgery.*

DOCTOR . . .

to help your *backache* patients resume some of their normal, happy activities, Simmons has invented *an entirely new kind of orthopedic-type mattress . . .*

BACK CARE *with Built-in Bedboard.*

THIS MATTRESS, developed in consultation with orthopedic surgeons, can be an important adjunct to the management of chronic backache and other disorders requiring a firm, comfortable sleeping surface.

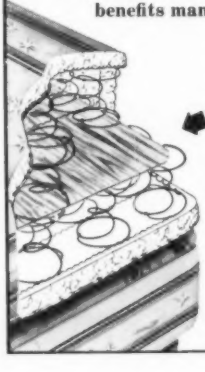
Many physicians use Back Care® in their homes for corrective action and sleeping comfort. Many more recommend it for patients.

For information on Back Care research, construction, testing, write to Simmons Co., Dept. BB, Merchandise Mart, Chicago, Ill. for the booklet called "The Prescription Mattress."

BACK CARE
WITH BUILT-IN BEDBOARD
by SIMMONS

© 1959 SIMMONS CO., MDSE. MART, CHICAGO, ILL.

Why Back Care's unique construction benefits many orthopedic patients



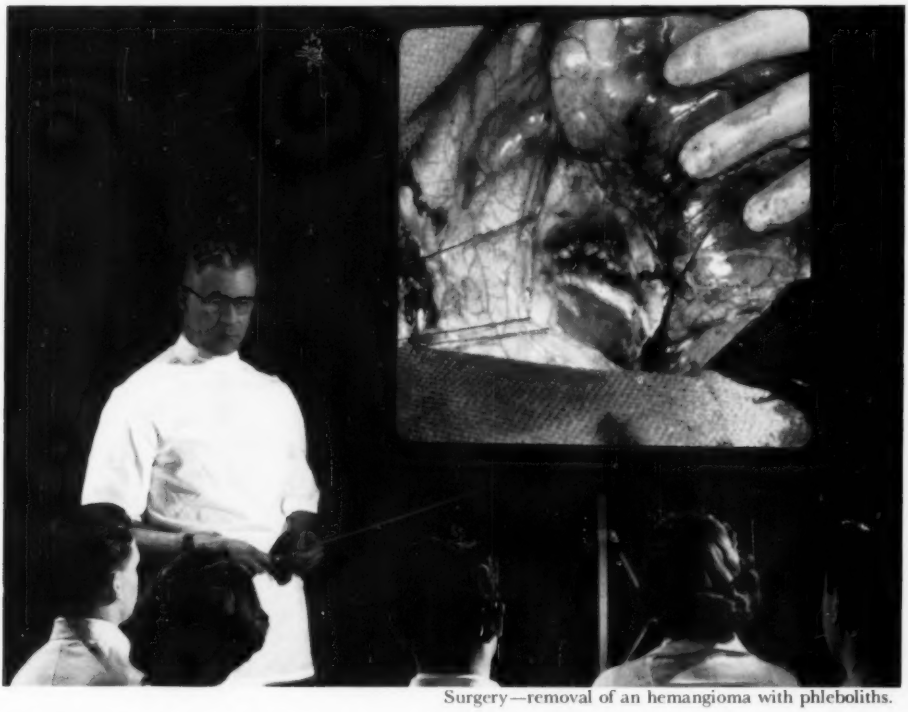
1. Upper layer of 312 coils adjusts to body contours for comfort.

2. This built-in *plywood* bedboard keeps the spine properly aligned . . . and exerts corrective action *close up to the back* where support is needed.

3. This lower layer of springs acts as "floating" mechanism for bedboard, equalizes weight over coils and prevents "sag."

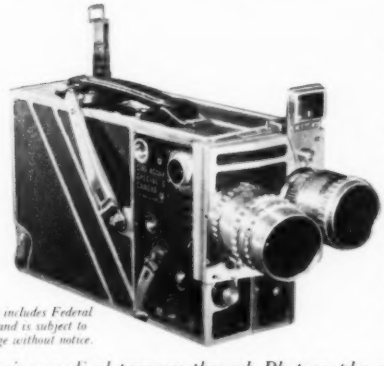
Nothing captures an audience like a motion picture

Whenever a procedure or technic needs to be presented, the motion picture can assist the explanation. What's more, it can be viewed again and again—tomorrow, next week . . . months from now. The only problem is to get it on film.



Surgery—removal of an hemangioma with phleboliths.

Nothing captures a picture like a Cine-Kodak Special II Camera



Price includes Federal Tax and is subject to change without notice.

Because of its ability to "get in there and get the picture" the "Special II" is on the job every day in the hands of skilled medical photographers. The "Special II" is well known for its dependability and convenience. Its variable-speed shutter, dual finder system, two-lens turret that accepts any two of the wide choice of great Kodak Cine Ektar Lenses, its interchangeable film chambers and many other features mean unsurpassed results. List, from $1,365.

For further information see your Kodak photographic dealer or write

EASTMAN KODAK COMPANY
Medical Division
Rochester 4, N. Y.

Kodak
TRADE MARK

Serving medical progress through Photography and Radiography

Richards

MARIO M. STONE TABLE STAPLE

(SMO)

No. 915 A
LARGE

No. 915 B
MEDIUM

No. 915 C
SMALL

PATENT PENDING

INDICATIONS

ORTHOPEDIC SURGERY

- Arthrodesis of the wrist,
- knee, ankle
- Triple Arthrodesis
- Epihyseal Arrest
- Advancement of Patella Supracondylar Osteotomy
- Pronated Pes Planus (talo-navicular)
- Equinovarus (calcaneo-cuboid)

TRAUMATIC SURGERY

- Fracture of Ankle
- Fracture Dislocation of Ankle
- Avulsion of Achillis Tendon
- Parrot-beak Fracture of Calcaneus
- Fracture of Greater Tuberosity of Humerus
- Abduction Fracture of Upper End of Humerus

No. 915 COMPLETE SET,
INCLUDES DRIVER EXTRACTOR
ONE DOZEN EACH A, B, C STAPLES.

The Mario M. Stone Table Staple offers multiple strength over ordinary staples, and prevents pivoting or shifting of the bone fragments. A center threaded hole engages driver and facilitates extraction.

RICHARDS MANUFACTURING COMPANY
756 MADISON AVE. — MEMPHIS, TENNESSEE

Richards

BOYES-PARKER HAND OPERATING TABLE

(U. S. PATENT NO. 2,609,261)

The surgeon and his assistant will find a scientifically designed workbench, efficient and steady, in the Boyes-Parker Hand Operating Table. It eliminates tension and strain during operations. Relieves cramped positions of the hands, arms and shoulders. Space for forearms and elbows improve operative steadiness without tiring, and can thus cut down operating time by 20%.

Removeable stainless steel pan facilitates washing.

Light in weight, easy for nurse to quickly place in position. Adjustable legs allow fitting to any operating table level. Collapsible; requires minimum of storage space.

Pull-out instrument board places instruments in ready position for use.

Formica top; all stainless steel parts; conductive rubber ends on feet.

No. 454	**BOYES-PARKER HAND OPERATING TABLE (Complete with No. 454A Pan)**	**$160.00**
No. 454A	**STAINLESS PAN ONLY**	**16.00**
No. 454B	**STAINLESS STEEL PAN WITH 1/4" DRAIN PLUG**	**20.00**

RICHARDS ADJUSTABLE SURGERY STOOL

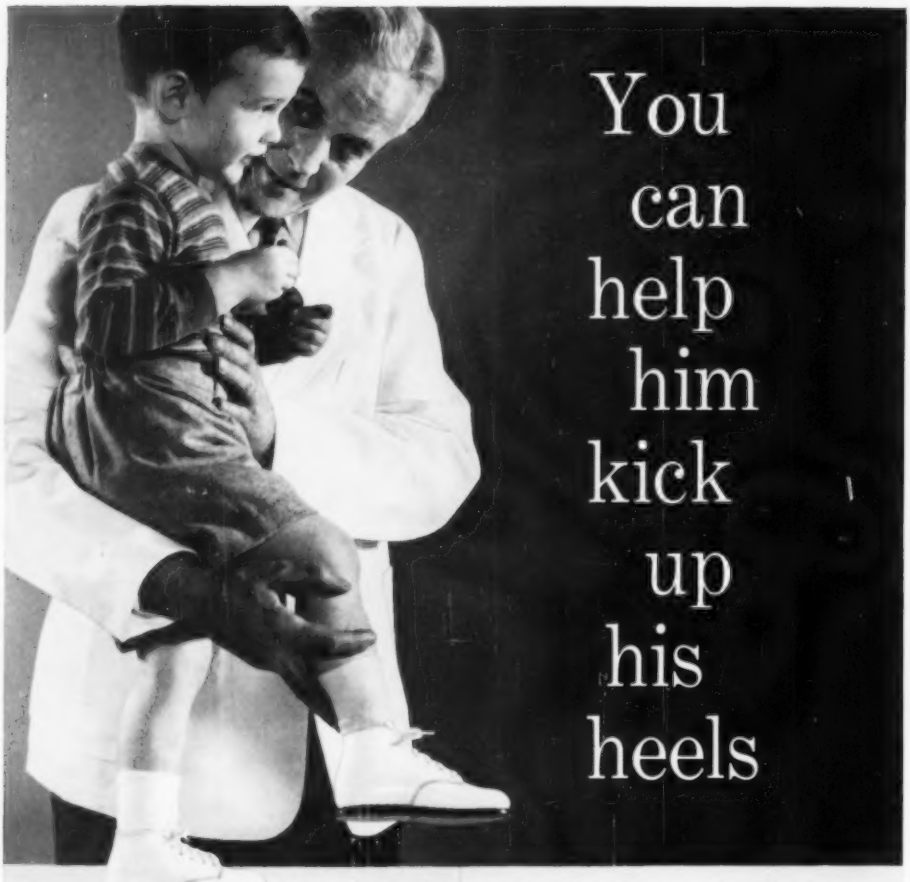
The Richards adjustable stool is designed primarily to be used with the Boyes-Parker Hand Operating Table. Constructed of durable steel tubing, chromium plated. Three legs give stability. The stool embodies the features of an ideal seat for the hand surgeon. The saddle shaped hardwood seat is firm and comfortable, with rounded edges.

The rigid stool does not swivel; there are no casters to slide. Simple and positive up and down adjustment. By sitting on a stool that does not pivot or wobble, the surgeon can maintain an efficient, tireless posture, resting the elbows on the projecting curves of the hand table.

No. 455 SURGERY STOOL.....$55.00

Richards MANUFACTURING CO., MEMPHIS, TENN.

In answering advertisements, please mention *The Journal of Bone and Joint Surgery*.



Babies are bundles of activity. As they grow, they channel their energy into pulling, pushing, crawling, and finally, one triumphant day, they're walking. If it's one of 'your' babies, you're just as proud as parents when you see a child running on strong legs and sturdy feet.

Edwards is proud as parents, too, because so many children learn to run and romp in Edwards shoes. Edwards dealers carry the three types of shoes shown below for all kinds of growing feet.

Edwards

Recommend and prescribe Edwards shoes for 'your' babies. For more information, send for Edwards brochure and prescription blanks.

PEDIC PRONA-PEDIC Edwards P P

The Shoe for Children, Philadelphia 7, Penna.

Edwards Todlins—for beginners, the tiny tots just learning to navigate.

Edwards Pedics—for children with foot disorders that you prescribe for.

Edwards Regulars — for normal healthy children's feet—with emphasis on proper fit.

Louis C. Weld, President, G. W. Chesbrough Co. . . . "My own personal experience led to the development of Chesbrough Orthopedic Pre-Walkers, club-foot, open toe and closed toe Surgicals."

"Orthopedic shoes parents can afford . . .

CHESBROUGH Corrective Pre-Walkers"

"When a child in my own family needed a corrective shoe, I discovered what a strain it can mean to a family budget, because 1) corrective footwear is expensive and 2) frequent purchase of new corrective shoes is required. Then and there I decided there was a real need for a moderately priced corrective shoe —a shoe parents could afford. That's why and when Chesbrough Orthopedic Pre-Walkers were born.

"Our 60 years of shoe-making experience resulted in corrective Pre-Walkers of scientific design, expert workmanship, fine leathers combined with orthopedically correct lasts to provide necessary correction at an economical price."

Today—just three years later—orthopedic specialists in 45 states and several foreign countries are prescribing these shoes.

All shoes in unlined white elk, sizes 000 to 4, narrow and wide. Available in full pairs, split pairs or single shoes (no extra charge for half pairs).

No. 1400 OPEN TOE. Straight-line symmetrical last, firm heel, no back seam. Adaptable to Denis Browne Splints.

No. 1700 CLUBFOOT, OPEN TOE. Special outflare last, sturdy instep strap to stabilize heel.

No. 1300 CLOSED TOE. Lace-to-toe design permits snug, gentle fit. Perfectly smooth inside.

MAIL COUPON FOR FREE DESK SAMPLES

G. W. CHESBROUGH CO.
807 Smith Street, Rochester 6, N. Y.

NAME.....

ADDRESS.....

CITY.....

YOUR ORTHOPEDIC SHOE DEALER:

.....

At zimmer micro-structure analysis of materials adds "extra" safeguard to your surgery

The chemical and physical properties of stainless steel delivered to Zimmer are certified by the manufacturer. *Still,* Zimmer subjects each shipment to its own rigorous micro-structure analysis. Result: An extra assurance that your implants and fixations will resist the destructive actions of body fluids.

Here's what happens to a typical shipment of certified stainless steel after it is delivered to the Zimmer laboratory:

- *Chemical and physical properties as stated in Vendor's Certificates are checked against material specifications.*
- *Samples are tested for hardness on a* Rockwell scale.
- *Samples are polished, etched . . . then checked for grain size and structural defects.*

If a discrepancy is found in a sample, the entire shipment is rejected. Micro-structure analysis of materials is one more "extra" you get from Zimmer's insistence on precise quality control . . . and one more reason why the Zimmer name has become a warranty of excellence.

zimmer®

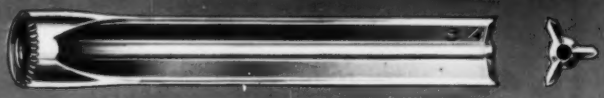
ZIMMER MANUFACTURING COMPANY

Warsaw, Indiana, U. S. A.

appliances for orthopedic surgery

zimmer®

JEWETT PLATE AND NAIL COMBINATION NO. 472



SMITH-PETERSEN NAIL NO. 96

LORENZO SCREW NO. 970

HIP SCREW NO. 259

ZIMMER TIBIA BOLT NO. 463

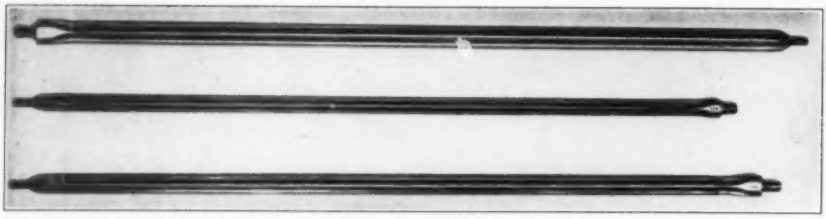
MODIFIED HAGIE PIN NO. 516

KNOWLES PIN NO. 281-A

ZIMMER MANUFACTURING CO. • WARSAW, INDIANA, U.S.A.

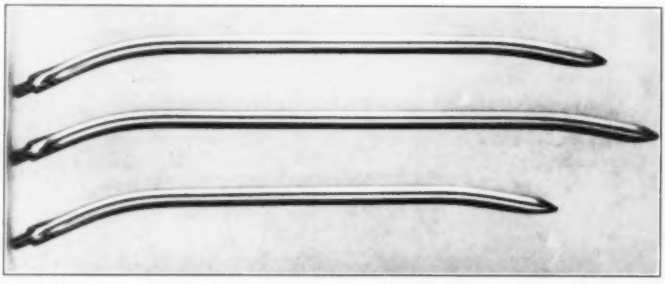
zimmer®

LOTTES NAILS and INSTRUMENTS

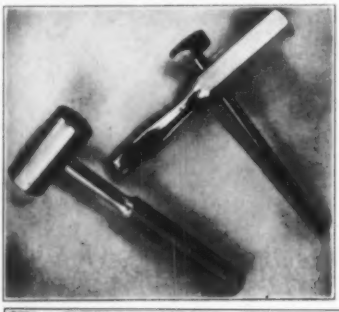


***LOTTES* FEMORAL NAILS** are manufactured with diameters of ⅜, 7/16, and ½ inches —with lengths in ½ inch variations from 14 to 20 inches.

***LOTTES* TIBIAL NAILS** are made in 5/16 and ⅜ inch diameters—in lengths from 9 to 15½ inches, in variation of ½ inch.



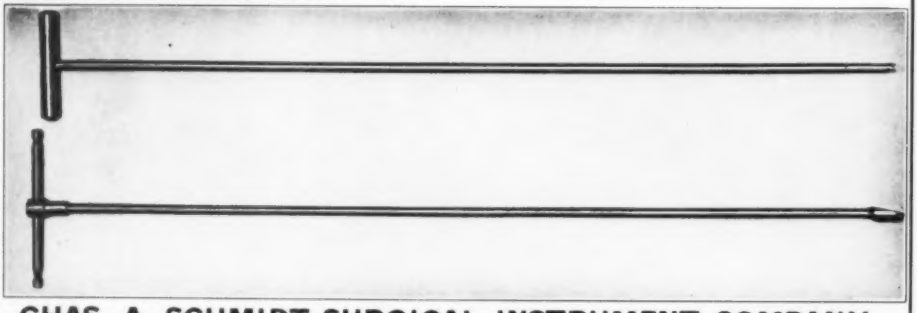
***LOTTES* NAILS AND INSTRUMENTS ARE MADE OF 18-8 SMo STAINLESS STEEL**



***LOTTES* DRIVER-EXTRACTOR COMBINATION and *LOTTES* MALLET**

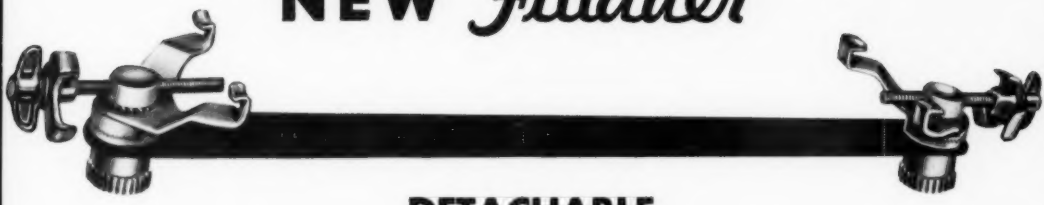
***LOTTES* GUIDE WIRE AND *LOTTES* REAMER**

The reamer comes in 3 diameters: ⅜, 7/16, and ½ inch—all are 23 inches in length.



CHAS. A. SCHMIDT SURGICAL INSTRUMENT COMPANY
3689 Olive Street, Saint Louis 8, Missouri

NEW Fillauer



DETACHABLE

DENIS BROWNE NIGHT SPLINT

STREAMLINED and IMPROVED

1. Precision die cast Serrated Discs permit 50 positions.
2. New Knurled Screw locks discs in position.
3. New Triple Flange fits club foot shoes or any sole thickness.
4. Streamlined Wing Screw secures flange to shoe sole.
5. Durable, attractive red alumilite color on bars.
6. Lengths 6, 7, 8, 9, 10, 12, 14, 16 and 18 inches. Special lengths to 30 inches at no extra cost.

ORTHOPEDIC SURGEONS recognize the decided advancements this versatile splint affords in treating club feet, positional deformities, tibial torsions, flat feet and congenital hip dislocations. Also applicable for any other deformities that are actively corrected by incessant kicking.

Very little adjustment by surgeon or orthotist is required to fit and position this new Fillauer Detachable Splint.

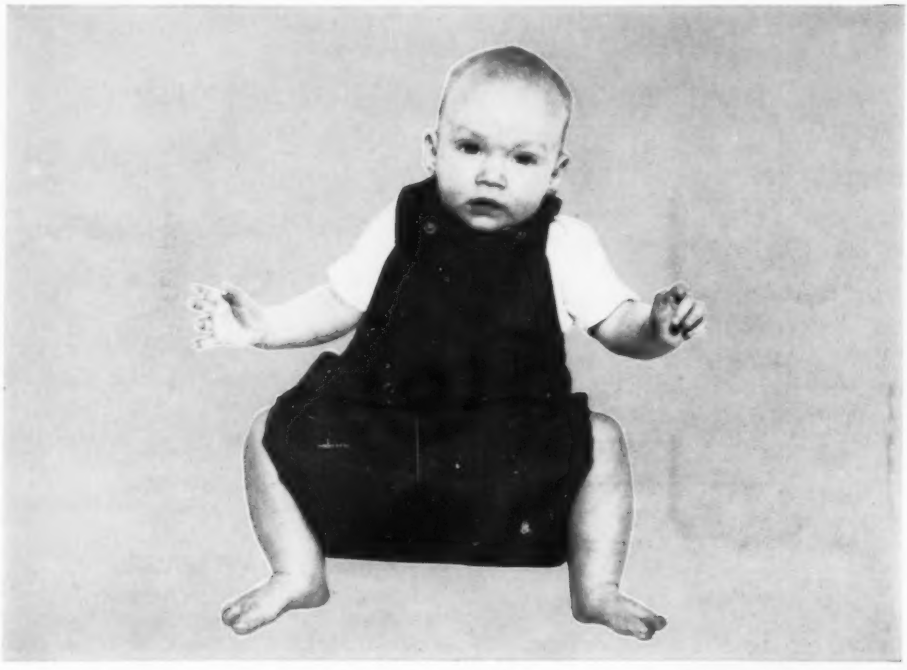
Pre-walker or larger surgical and club foot shoes work extremely well with the Fillauer Splint. Outgrown shoes may be used by cutting out toes.

Fillauer SURGICAL SUPPLIES, INC.
BOX 1678 CHATTANOOGA, TENN.
ESTABLISHED 1914 Manufacturers of Orthopedic Supplies

ORTHOPEDIC APPLIANCE & LIMB MANUFACTURERS ASSOCIATION AMA

CAMP HIP ABDUCTION PILLOW

effective therapy at home



An abduction pillow splint is a practical, atraumatic method for gradually obtaining hip abduction in infants with abduction contractors, unilateral or bilateral hip dysplasia and many cases of congenital dislocation. It is also an effective means of maintaining abduction following more severe dislocations requiring rigid immobilization or surgery. This type of pillow splint is well tolerated, permits the child to sit or stand while maintaining the abduction position.

In addition to the Camp regular Frejka type pillow this new, improved Camp pillow splint fits the contour of the legs to bring the child to frog-like position. Adjustable for leg size; a plastic water resistant pillow held in a pocket of the bib; crossed adjustable shoulder straps, all with gripper snap fasteners for easy application. Bib is made of a soft attractive cotton fabric, with an extra bib to use while one is being laundered, without interruption of treatment.

Three sizes (pillow width between legs)—Small 6″, Medium 9″, Large 12″.

S. H. CAMP and COMPANY CAMP TRADE MARK Jackson, Michigan

In answering advertisements, please mention *The Journal of Bone and Joint Surgery.*

even if your patient is a boom rat

*logger who rafts logs in a "boom"

he'll be pulling down his pay again soon thanks to

PARAFON

(PARAFLEX® + TYLENOL®)

for muscle relaxation *plus* analgesia

prescribe PARAFON in low back pain—sprains—strains—rheumatic pains

Each PARAFON tablet contains:
PARAFLEX® Chlorzoxazone‡ ..... 125 mg.
A most effective oral muscle relaxant
TYLENOL® Acetaminophen ..... 300 mg.
The preferred analgesic for painful musculoskeletal disorders

Dosage: Two tablets t.i.d. or q.i.d.

Supplied: Tablets, scored, pink, bottles of 50.

and in arthritis

PARAFON WITH PREDNISOLONE

Each PARAFON WITH PREDNISOLONE tablet contains: PARAFLEX® Chlorzoxazone‡ 125 mg., TYLENOL® Acetaminophen 300 mg., and prednisolone 1.0 mg.

Supplied: Tablets, scored, buff colored, bottles of 36.

Precautions: The precautions and contraindications that apply to all steroids should be kept in mind when prescribing PARAFON WITH PREDNISOLONE.

McNeil Laboratories, Inc • Philadelphia 32, Pa.

‡ Trademark U. S. Patent Pending

24AA53

FOR GREATER STRENGTH AND SAFETY—

DEMAND GENUINE **NEUFELD NAILS** *and* **SCREWS**

—IN **NEUTRILIUM®**

NEUTRILIUM® is the most non-corrosive metal known to science. Its proven super-strength lends an assurance of permanence to internal fixation of the trochanteric area. This neutral, non-magnetic, homogenetic alloy is entirely inert and therefore compatible with human bone or tissue, remaining unaffected by body chemistry.

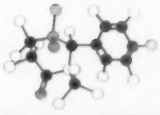
NEUFELD BONE SCREWS — of ***NEUTRILIUM®*** — are cold forged and, unlike other metals, appear to be unbreakable under maximum human pressures. Heads will not twist off during application or in actual use.

GENUINE NEUFELD NAILS and SCREWS — of ***NEUTRILIUM®*** — made only by MEDICAL RESEARCH SPECIALTIES, Loma Linda, California, are sold nationally by leading surgical and orthopaedic supply dealers.

***NEUTRILIUM®** is a registered Trade Name of Medical Research Specialties.*

NEUFELD FEMORAL NAIL PLATE
Used for internal fixation of intertrochanteric and subtrochanteric fractures.
Write for descriptive literature
MEDICAL RESEARCH SPECIALTIES
Loma Linda, California

new



Trancopal®

*the first true tranquilaxant**

Potent **MUSCLE RELAXANT** . . . *Equally effective as a* **TRANQUILIZER**

in musculoskeletal conditions[1]	in anxiety and tension states[1]
effective in 91% of patients	effective in 88% of patients
Low back pain (lumbago) Bursitis Osteoarthritis Fibrositis Myositis Postoperative myalgias Neck pain (torticollis) Rheumatoid arthritis Disk syndrome Joint disorders (ankle sprain, tennis elbow, etc.)	Anxiety and tension states Premenstrual tension Emphysema Dysmenorrhea Asthma Angina pectoris

Better tolerated and safer than older drugs[2]

With Trancopal there is no clouding of consciousness, no euphoria or depression. Even in high dosage, there is no perceptible soporific effect. Because it does not irritate gastric mucosa, it can be taken without regard to mealtimes. Administration does not hamper work — or play. There are no known contraindications. Blood pressure, pulse rate, respiration and digestive processes are unaffected by therapeutic dosage. Toxicity is extremely low. And Trancopal has a lower incidence of side effects than has zoxazolamine, methocarbamol or meprobamate.

Dosage: One Caplet (100 mg.) orally three or four times daily. Relief of symptoms occurs in fifteen to thirty minutes and lasts from four to six hours.

Supplied: Trancopal Caplets® (scored) 100 mg., bottles of 100.

References: 1. Cooperative Study of 4092 patients by 105 physicians, Department of Medical Research, Winthrop Laboratories. 2. Lichtman, A.L.: Kentucky Acad. Gen. Pract. J. 4:28, Oct., 1958.

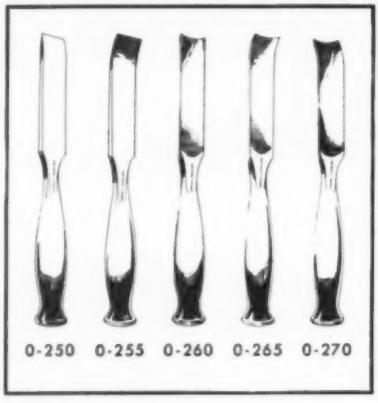
*tran'kwi-lak'sant [<L. *tranquillus*, quiet; L. *laxare*, to loosen, as the muscles]

Trancopal (brand of chlormezanone) and Caplets, trademarks reg. U.S. Pat. Off.,

Winthrop LABORATORIES
New York 18, New York

1349M

SMITH-PETERSEN OSTEOTOMES and GOUGES



0-250 0-255 0-260 0-265 0-270

0-250 SMITH-PETERSEN OSTEOTOME—straight, 8", sizes ¼", ⅜", ½", ⅝", ¾", 1" and 1¼". Stainless Steel.

0-255 SMITH-PETERSEN OSTEOTOME—curved, 8", sizes ¼", ⅜", ½", ⅝", ¾", 1" and 1¼". Stainless Steel.

0-260 SMITH-PETERSEN GOUGE—straight, 8", sizes ⅜", 9/16", ¾" and 1". Stainless Steel.

0-265 SMITH-PETERSEN GOUGE—curved, 8", sizes ⅜", 9/16", ¾" and 1". Stainless Steel.

0-270 SMITH-PETERSEN GOUGE—reverse curved, 8", sizes ⅜", 9/16", ¾" and 1". Stainless Steel.

A NEW STAINLESS STEEL CASE TO HOLD SMITH-PETERSEN OSTEOTOMES and GOUGES

0-295 Open

CASE 0-295—holds seven Smith-Petersen Osteotomes.

CASE 0-296—holds seven Smith-Petersen Gouges.

CASE 0-297—holds a combination of seven Osteotomes and Gouges.

Cutting edges are protected at all times. Complete unit may be autoclaved.

0-295 Closed

Specify Width of Gouges and Osteotomes When Ordering

ESTABLISHED 1838

Codman & Shurtleff, Inc.

MAKERS OF SURGEONS' INSTRUMENTS

104 BROOKLINE AVENUE BOSTON 15, MASSACHUSETTS

Before and after surgery

effective for anxiety, tension and insomnia

- reduces preoperative fear
- helps ensure natural sleep without morning hang-over
- no significant lowering of blood pressure
- no respiratory depression
- well tolerated, relatively nontoxic

Miltown®

THE ORIGINAL MEPROBAMATE
DISCOVERED & INTRODUCED BY
WALLACE LABORATORIES
NEW BRUNSWICK, NEW JERSEY

REFERENCES:

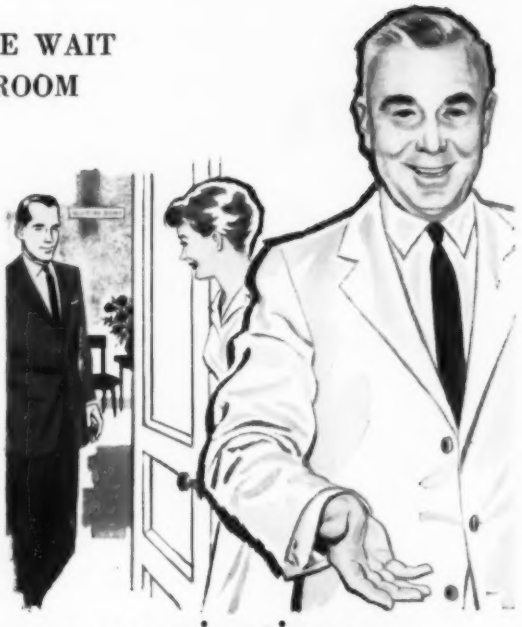
1. *Rushia, E. L.: Preliminary report on the use of meprobamate for pre-anesthetic sedation. J.M.A. Georgia* **46**:*93, March 1957.*
2. *Lamphier, T. A.: The role of meprobamate in postoperative surgical care. Ann. New York Acad. Sc.* **67**:*810, May 9, 1957.*
3. *Kern, E. C.: Preoperative sedation with meprobamate (Miltown) in surgery of eye, ear, nose and throat. Eye, Ear, Nose & Throat Month.* **36**: *408, July 1957.*

CM-6086

SUSAN'S IDEA TOOK THE WAIT OUT OF THE WAITING ROOM

She kept complaining about my old x-ray machine — said she could accomplish more if only she had that new G-E unit I'd talked about. She'd have fewer retakes too — most of them were caused by the long exposures necessary with low power.

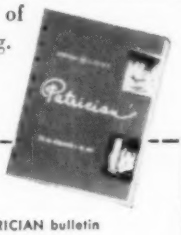
From the day my new Patrician combination arrived I'm sure Susan felt her persistence had turned the trick. (And you know — she *is* working faster today!)



Patrician speeds x-ray examinations

. . . and for such modest cost

You'll find your work load lighter with Patrician's big-table convenience. Best news is 200-ma, 100-kvp power, electronically timed. Self-tending reciprocatic Bucky. Finger-tip control of fluoroscopic screen or optional spot-film device. Angulation to 15° Trendelenburg. Automatic Bucky-slot closures for x-ray safety. Ask your G-E x-ray representative for full details. Or clip coupon for a copy of our fully illustrated catalog.



X-RAY DEPARTMENT
GENERAL ELECTRIC CO.
Milwaukee 1, Wisconsin, Rm. CF-41

- ☐ Please send me your 16-page PATRICIAN bulletin
- ☐ Facts about deferred payment
- ☐ MAXISERVICE ® rental

Name .....

Address .....

.....

Progress Is Our Most Important Product

GENERAL ELECTRIC

to control nausea,
vomiting, or retching—
before, during, or
after surgery

Compazine*

- hypotensive effects are minimal and infrequent—even during spinal anesthesia
- may be administered I.V., as well as I.M., orally, or rectally
- minimal potentiation of C.N.S. depressants
- pain at the site of injection has not been a problem

For immediate effect: 2 cc. Ampuls (5 mg./cc.) and 10 cc. Multiple dose vials (5 mg./cc.).
Also available: Tablets, Spansule† sustained release capsules, Suppositories and Syrup.

Smith Kline & French Laboratories

*T.M. Reg. U.S. Pat. Off. for prochlorperazine, S.K.F. † T.M. Reg. U.S. Pat. Off.

Child Life SHOES provide

Winged Mismate Service

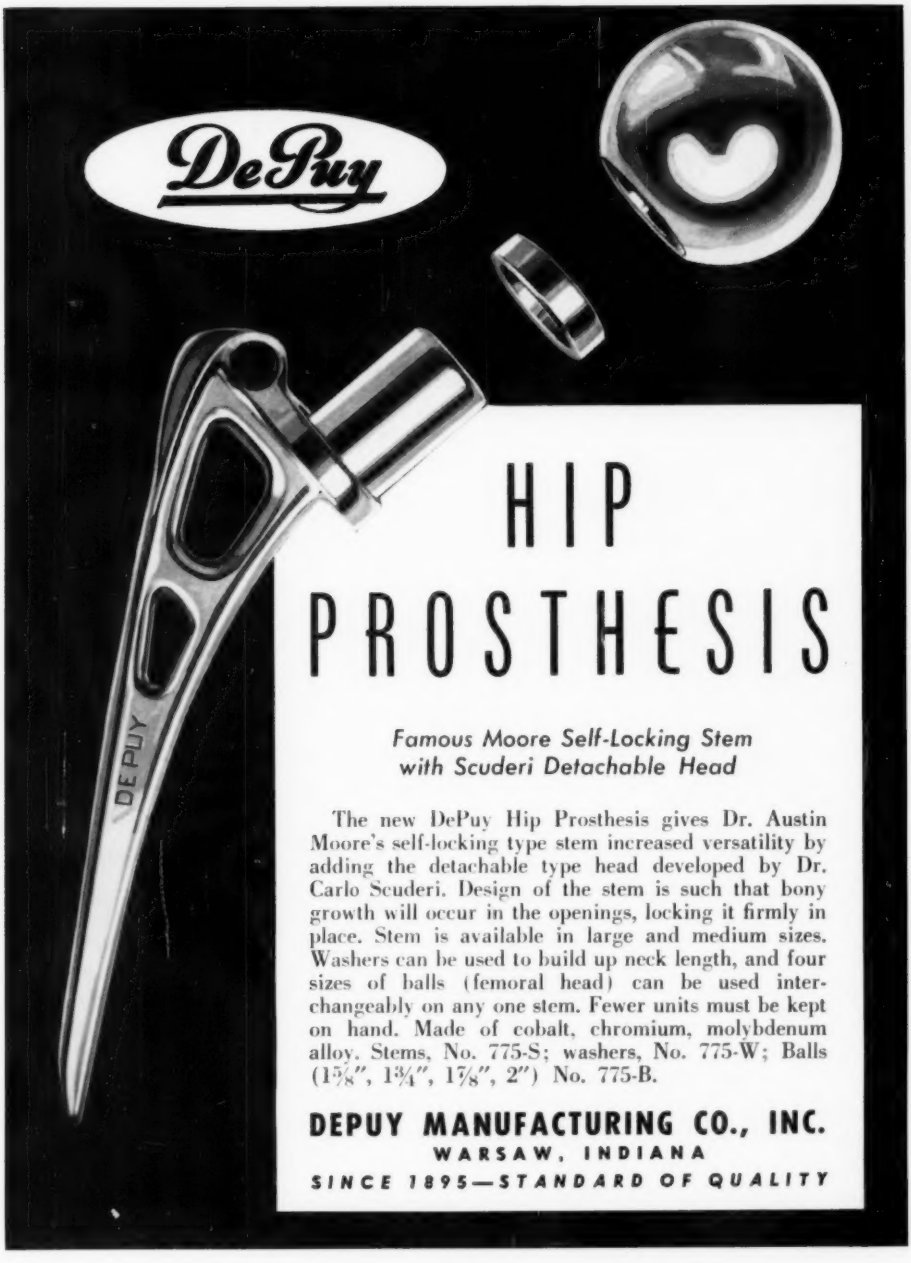
When mismated shoes are needed, they are needed NOW — not two or three weeks hence. The sooner the shoes arrive, the better for your patient. Because this is so true — and human comfort is important — CHILD LIFE gives special priority to Mismate Service. In nine cases out of ten, shoes are shipped the same day the order is received . . . and they are sent *special delivery* parcel post.

As a physician, it's good to know that this brand of service backs up your recommendations to mothers. And it's good to know, too, that CHILD LIFE Mismate Service carries only a very nominal premium in price. The CHILD LIFE dealer in your community — selected for his special knowledge of children's shoes — will be glad to fill you in on all details. Please write for his name.

Or if you prefer to write direct for information, your inquiry will be welcome and promptly acknowledged.

HERBST SHOE MANUFACTURING COMPANY
MILWAUKEE 45, WISCONSIN

NEW



HIP PROSTHESIS

Famous Moore Self-Locking Stem with Scuderi Detachable Head

The new DePuy Hip Prosthesis gives Dr. Austin Moore's self-locking type stem increased versatility by adding the detachable type head developed by Dr. Carlo Scuderi. Design of the stem is such that bony growth will occur in the openings, locking it firmly in place. Stem is available in large and medium sizes. Washers can be used to build up neck length, and four sizes of balls (femoral head) can be used interchangeably on any one stem. Fewer units must be kept on hand. Made of cobalt, chromium, molybdenum alloy. Stems, No. 775-S; washers, No. 775-W; Balls (1⅝", 1¾", 1⅞", 2") No. 775-B.

DEPUY MANUFACTURING CO., INC.
WARSAW, INDIANA
SINCE 1895—STANDARD OF QUALITY

In answering advertisements, please mention *The Journal of Bone and Joint Surgery*.

NOW—YOU CAN GET THE
UNSURPASSED ADVANTAGES
OF ARISTOCORT
IN SALICYLATE
COMBINATION

Aristogesic combines the *anti-inflammatory* effects of Aristocort® Triamcinolone with the *analgesic* action of a most potent salicylate. This means that the dosage of each is *substantially lower* than that ordinarily required for each agent alone. With Aristogesic the physician has exceptionally wide latitude in adjusting the dosage to the lowest effective level.

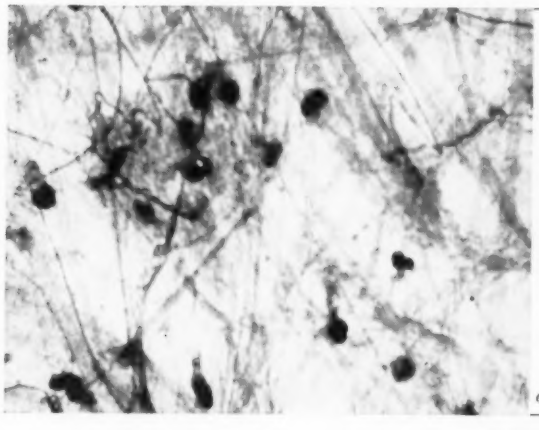
The possibility of gastric distress from either salicylamide or corticosteroid is minimized because of lower dosage required. This is further reduced by the buffer action of aluminum hydroxide. And the ascorbic acid helps meet the increased need for this vitamin in stress conditions. Because of the low dosage, side effects with Aristogesic have been relatively infrequent and minor in nature. However, more serious side effects have traditionally been observed on all corticosteroid therapy. Patients on long-term Aristogesic therapy should, therefore, be observed carefully.

In answering advertisements, please mention *The Journal of Bone and Joint Surgery*.

ogesic*

Steroid–Analgesic Compound LEDERLE

for relief of *chronic*—but *less severe* pain of rheumatic origin



Indications: Mild cases of rheumatoid arthritis, tenosynovitis, synovitis, bursitis, mild spondylitis, myositis, fibrositis, neuritis and certain muscular strains.

Dosage: Average initial dosage: 2 capsules 3 or 4 times daily. Maintenance dosage to be adjusted according to response.

Each Aristogesic Capsule contains:

ARISTOCORT® Triamcinolone	0.5 mg.
Salicylamide	325 mg.
Aluminum Hydroxide	75 mg.
Ascorbic Acid	20 mg.

Supply: Bottles of 100.

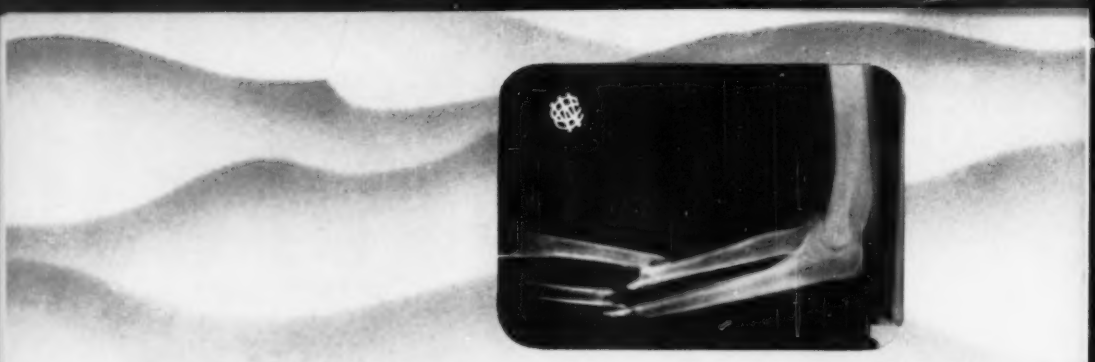
Collagen tissue (x250)

*TRADEMARK

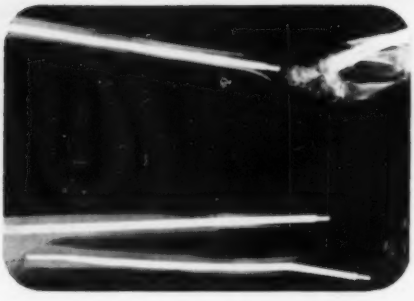
Lederle

LEDERLE LABORATORIES, A Division of AMERICAN CYANAMID COMPANY, Pearl River, New York

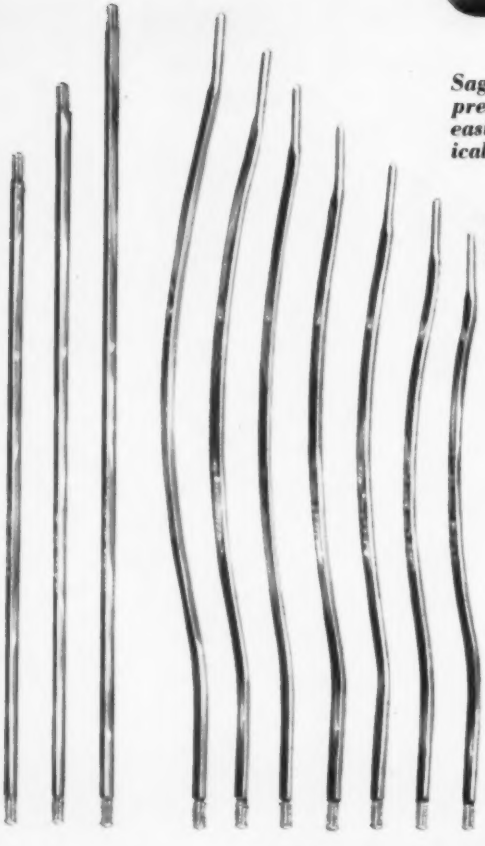
In answering advertisements, please mention *The Journal of Bone and Joint Surgery.*



sage pins



Sage Triangular Forearm Pins have precision formed contours to allow easier insertion and aid in anatomical alignment.

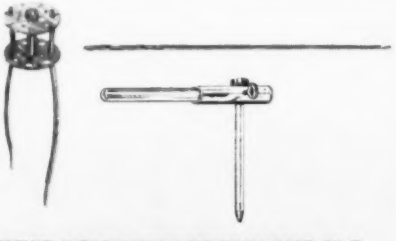


MADE OF NON-MAGNETIC, INERT, SMO STAINLESS STEEL . . . SPRING TEMPERED TO A SPECIAL ROCKWELL-HARDNESS.

Pre-formed (one end threaded) Radius Pins available in seven lengths, graduated in ½-inch increments from 8 to 11 inches. Straight (both ends threaded) Ulna Pins available in three lengths, graduated in 1-inch increments from 9 to 11 inches. Radius and Ulna Pin diameters are either 4.4 mm or 5 mm.

COMPLETE SET CONSISTS OF SEVEN RADIUS PINS, THREE ULNA PINS AND PIN HOLDING RACK.

THE REAMER DRILL AND DRIVER EXTRACTOR ARE ESPECIALLY DESIGNED FOR USE WITH THESE PINS. THE DRILLS ARE CORRECTLY SIZED TO ASSURE EASY INSTALLATION AND MAXIMUM HOLDING POWER.



WRIGHT MANUFACTURING COMPANY

FOR FURTHER INFORMATION WRITE TO DEPT. W-7

880-882 ADAMS, MEMPHIS, TENNESSEE

PAIN Zactirin®

Ethoheptazine Citrate with Acetylsalicylic Acid, Wyeth

for everyday pain control . . .

for your many patients requiring potent analgesia but not an injected narcotic

Proved by extensive evaluation[1,2,3] in 1998 patients in diverse areas of medicine and surgery, including:

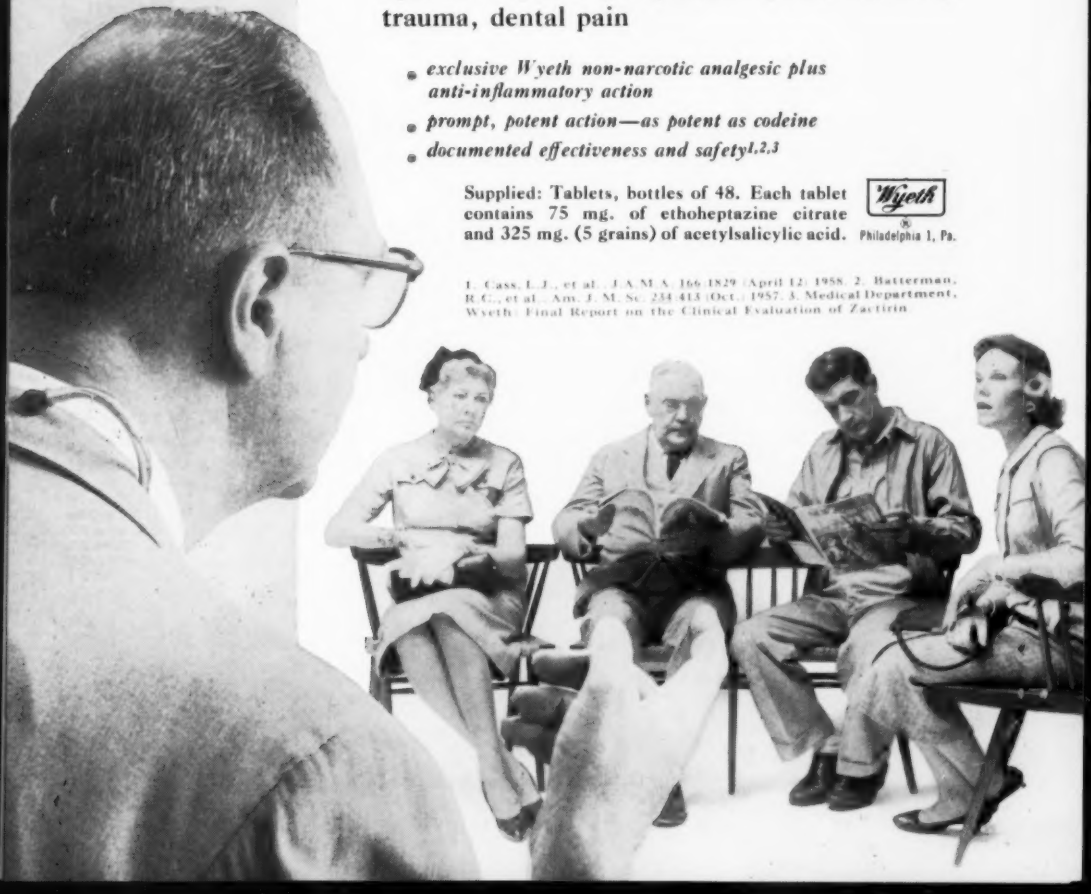
arthritis, bursitis, early metastatic carcinoma, fibrositis, grippe, herpes zoster, ligamental strain, low back pain, menstrual pain, myalgia, myositis, neuritis, pleurisy, postoperative pain, postpartum pain, sciatica, trauma, dental pain

- *exclusive Wyeth non-narcotic analgesic plus anti-inflammatory action*
- *prompt, potent action—as potent as codeine*
- *documented effectiveness and safety[1,2,3]*

Supplied: Tablets, bottles of 48. Each tablet contains 75 mg. of ethoheptazine citrate and 325 mg. (5 grains) of acetylsalicylic acid.

Wyeth® Philadelphia 1, Pa.

1. Cass, L. J., et al.: J.A.M.A. 166:1829 (April 12) 1958. 2. Batterman, R.C., et al.: Am. J. M. Sc. 234:413 (Oct.) 1957. 3. Medical Department, Wyeth: Final Report on the Clinical Evaluation of Zactirin.



KENACORT

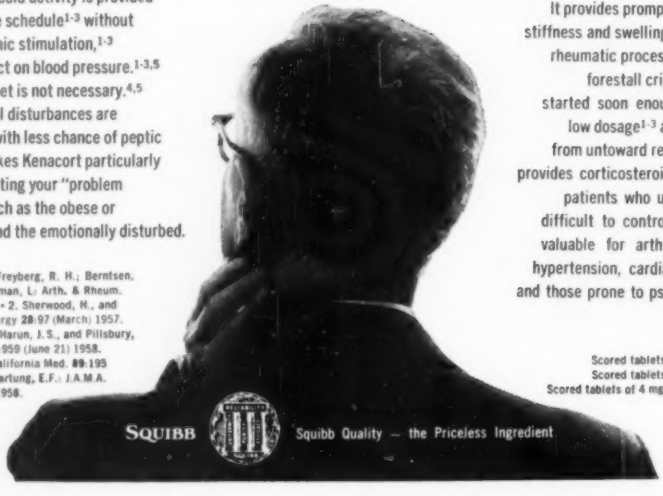
SQUIBB TRIAMCINOLONE

for all your patients starting on corticoids

Kenacort safely starts your patients off right — with all the benefits of systemic corticosteroid therapy and few side effects to worry about. Increased corticoid activity is provided on a low dosage schedule[1-3] without edema,[1-4] psychic stimulation,[1-3] or adverse effect on blood pressure.[1-3,5] A low sodium diet is not necessary.[4,5] Gastrointestinal disturbances are negligible[2,4,5] with less chance of peptic ulcer.[4] This makes Kenacort particularly valuable in treating your "problem patients" — such as the obese or hypertensive and the emotionally disturbed.

for all your arthritic patients requiring corticoids

Kenacort, particularly in the treatment of your arthritic patients, has proved effective where other steroids have failed. It provides prompt, safe relief of pain, stiffness and swelling by suppressing the rheumatic process[1,5] — and may even forestall crippling deformities if started soon enough. Because of its low dosage[1-3] and relative freedom from untoward reactions,[1-5] Kenacort provides corticosteroid benefits to many patients who until now have been difficult to control. It is particularly valuable for arthritic patients with hypertension, cardiac disease, obesity and those prone to psychic disturbances.



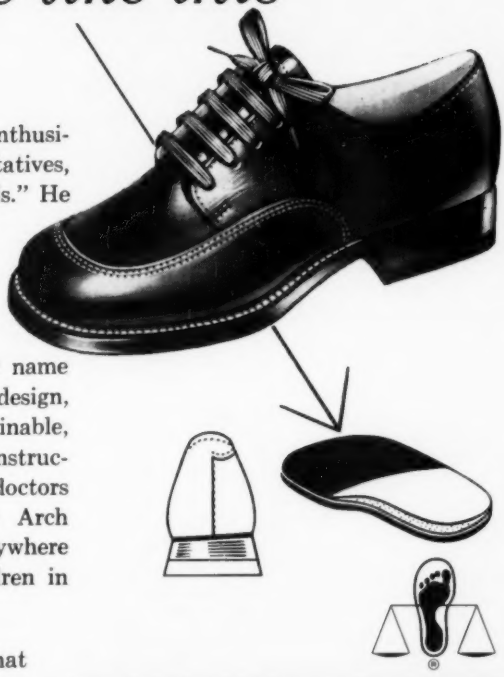
SUPPLIED:
Scored tablets of 1 mg. — Bottles of 50
Scored tablets of 2 mg. — Bottles of 50
Scored tablets of 4 mg. — Bottles of 30 and 100

REFERENCES: • 1. Freyberg, R. H.; Berntsen, C. A., Jr., and Hellman, L.: Arth. & Rheum. 1:215 (June) 1958. • 2. Sherwood, H., and Cooke, R. A.: J. Allergy 28:97 (March) 1957. • 3. Shelley, W. B.; Harun, J. S., and Pillsbury, D. M.: J.A.M.A. 167:959 (June 21) 1958. • 4. Dubois, E.L.: California Med. 89:195 (Sept.) 1958. • 5. Hartung, E.F.: J.A.M.A. 167:973 (June 21) 1958.

SQUIBB — Squibb Quality — the Priceless Ingredient

'KENACORT'® IS A SQUIBB TRADEMARK

Only Medic makes a shoe like this



A DOCTOR recently exclaimed enthusiastically to one of our representatives, "Only Medic makes a shoe like this." He happened to be holding in his hand a pair of Junior Arch Preservers with wedge construction.

The fact is every pair of shoes bearing the Junior Arch Preserver name is made with equal excellence in design, the very finest quality leathers obtainable, and the greatest possible care in construction. That's why more and more doctors prescribe and recommend Junior Arch Preserver Shoes — recognized everywhere as the finest shoes made for children in America today.

Also recognized is the fact that Medic makes a shoe to fill every doctor's shoe prescription needs.

For the name and address of the store nearest you carrying Junior Arch Preservers, write directly to

Medic Shoe Manufacturers, Inc.

1212 WOOD STREET,
PHILADELPHIA 7, PA.

Junior
ARCH PRESERVER
Shoes
by
MEDIC

The complete line of feature shoes for children that doctors recommend

LaBerne Shoulder Rotator

The LaBerne Shoulder Rotator offers Progressive and Resistive Exercises in a complete range, for Internal and External Rotation, Unilateral and Bilateral Extensor, Scapula Rotation, and Elbow Flexor Exercise. Built with Sensitive Resistance-Pressure Plate adjustable in height. Calibrated for 0 to 80 lbs.

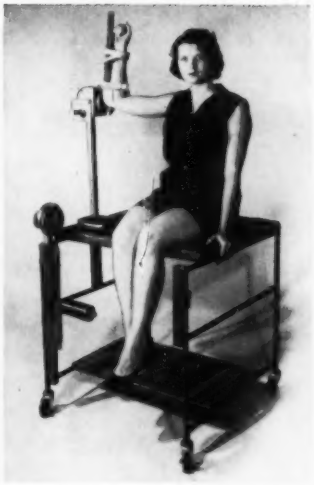
Price including table 28 x 30 x 32

Model # 9952 $159.50

Price without table with bracket for attaching to plinth,

Model # 9952-A $ 89.50

Showing Resistance Control Calibration in pounds. →



LaBerne Extension-Flexion Exercise Unit

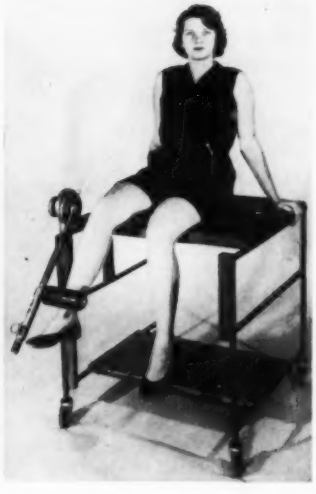
Designed for a complete range of Progressive Resistive Exercise to the Knee Joint Muscle Group WITHOUT THE USE OF WEIGHTS.

Exercise arm built with Reversible Ratchet on Sensitive Pressure Plate offering any desired resistance calibrated in lbs. from 0 to 80. Range of motion indicator in full view of patient and therapist for accurately following Range Progress. Ideal for use with BK Amputees and BK Fractures, may also be used for Hamstring Exercise, Hip Abduction and Extension. Complete unit including table 28 x 30 x 32 with Quadriceps Rest, Model # 9950

$159.50

Above unit with Shoulder Rotator included, Model # 9951 $239.00

Showing use for BK amputees and fractures. Range of motion dial calibrated in pounds. →



LaBerne Hip Rotator

Designed for complete rotation of Hip Joint. Rotation Plate built at 8° angle to eliminate bending of knee during rotation. Mounted on roller bearings with Adjustable Arc from 4" to 12" circle. Model # 66 $49.50

ALL PRICES FOB COLUMBIA

La Berne MANUFACTURING COMPANY

Columbia, S.C. P.O. Box 5245 Phone SUnset 7-6162

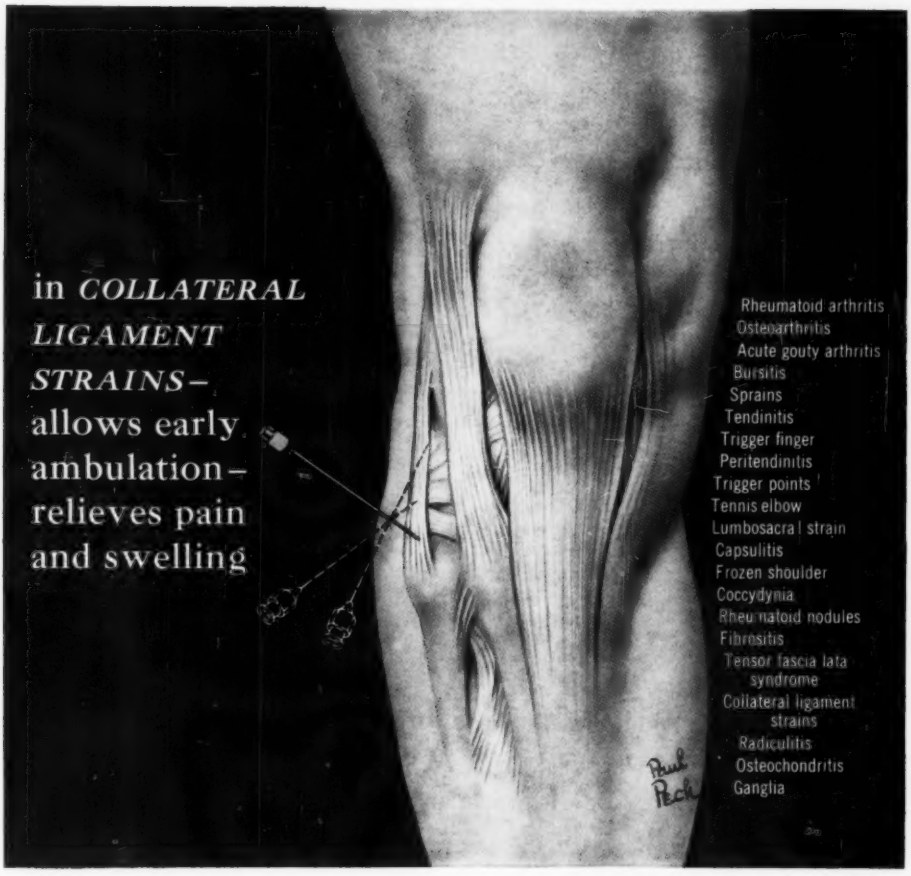
ORIGINATORS OF THE "WALK-OFF" PHYSICAL THERAPY TABLE

In answering advertisements, please mention *The Journal of Bone and Joint Surgery*.

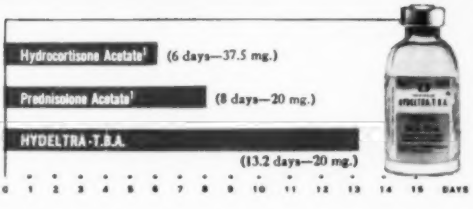
HYDELTRA® -T.B.A.

(Prednisolone *tertiary*-butylacetate, Merck)

for relief that lasts—longer



Duration of relief exceeds that provided by any other steroid ester


Hydrocortisone Acetate[1] (6 days—37.5 mg.)
Prednisolone Acetate[1] (8 days—20 mg.)
HYDELTRA-T.B.A. (13.2 days—20 mg.)
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 DAYS

Dosage: the usual intra-articular, intra-bursal or soft tissue dose ranges from 20 to 30 mg. depending on location and extent of pathology.

Supplied: Suspension "HYDELTRA"-T.B.A.—20 mg./cc. of prednisolone *tertiary*-butylacetate in 5-cc. vials.

MERCK SHARP & DOHME
DIVISION OF MERCK & CO., INC.
PHILADELPHIA 1, PA.

YOU'LL BE GLAD TO PRESCRIBE

Alden-Pedic

SCIENTIFIC CONSTRUCTION SHOES

Style No. 84

Alden-Pedic lasts and shoes are scientifically designed to fit the individual foot shape and at the same time accommodate your prescribed corrections and insertions without sacrificing any fitting qualities. Alden-Pedic shoes are basic prescription shoes. We do not manufacture a pre-corrected or commercial health shoe.

Orthopedic surgeons familiar with the Alden-Pedic program have achieved most satisfactory results in recommending our shoes.

Write us today for our new illustrated brochure of Alden-Pedic styles for men and boys and our new "Progress Report on Shoe and Last Design".

Developed through our modern research program

- Long inside counter
- Right and left ortho heels, long inside
- Heavy gauge right and left ribbed steel shank.
- New "Depth Design" accommodates prescribed corrections

C. H. ALDEN SHOE COMPANY

Custom Bootmakers Since 1884

BROCKTON, MASSACHUSETTS

FOR BOOKLET AND NAME OF NEAREST DEALER WRITE

Precise Positioning and Positive Fixation—

with AMERICAN-Albee

ORTHOPAEDIC *and* FRACTURE TABLE

● Acknowledged as the most versatile in its field, the American-Albee Orthopaedic and Fracture Table enables the orthopaedic surgeon to achieve "perfect positioning" of short, tall, obese and even infant patients . . . easily and rapidly. It is designed to accommodate closed fracture reductions as well as the increasing demands of complex orthopaedic surgery. Thus, to orthopaedists the world over, the name American-Albee identifies the table of choice for this comprehensive branch of medicine.

Ideal complement to this improved table is the American DV-22 Major Surgical Light . . . a new concept in easily maneuverable illumination . . . cool, shadowless, color-corrected . . . intensity to 10,000 foot candles *from a dual source.*

● *Write for Fracture Table Brochure TC-100R and Major Light Catalog LC-121R.*

Offices in 14 Principal Cities

AMERICAN STERILIZER

ERIE • PENNSYLVANIA

A totally new concept in patient handling

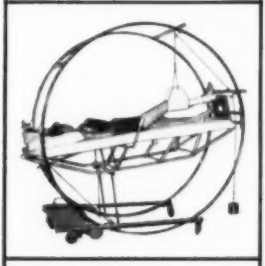
Introducing the

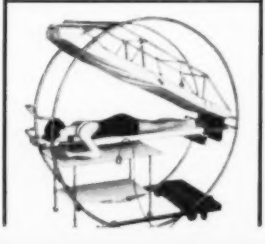
Stryker CircOelectric

UNIVERSAL HOSPITAL BED

Designed specifically for improved handling and care of the orthopedic patient. An ideal bed for management of every orthopedic problem. The bed may be electrically operated by the patient to save valuable nursing time for more demanding duties.

Have this practical bed demonstrated for you by Lee Stryker, Don Carson, Marshall Morrison, or Pete Hoffman at booth 74, 75, or 76 during the American Academy of Orthopedic Surgeons Meeting, January 24th to 29th.

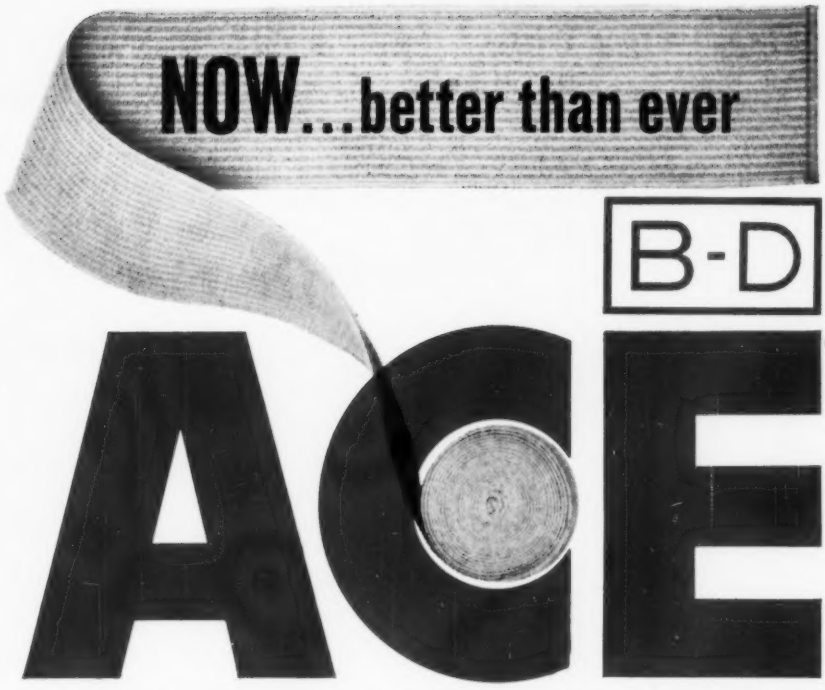




Stryker Manufacturers of Quality Surgical and Hospital Equipment

Orthopedic Frame Company

420 ALCOTT STREET • KALAMAZOO, MICHIGAN



RUBBER ELASTIC BANDAGE

ASSURES MORE UNIFORM SUPPORT

Scientifically determined number of rubber and cotton threads provides a **balanced weave** that assures optimal therapeutic results.

ACE guarantees even and controlled stretch

ACE insures firmness under tension

ACE prevents "bunching"

ACE minimizes possibility of vein constriction

MAINTAINS ITS ELASTICITY LONGER

Today, ACE provides your patient with anatomically correct support far longer. B-D's newly developed type of heat-resistant rubber can withstand dry heat sterilization and has a greater tensile strength than rubber found in ordinary bandages.

Now, more than ever, ACE is the name to remember. Only Becton, Dickinson and Company makes ACE rubber elastic bandage.

BECTON, DICKINSON AND COMPANY · RUTHERFORD, NEW JERSEY

B-D AND ACE ARE REGISTERED TRADEMARKS OF BECTON DICKINSON AND COMPANY

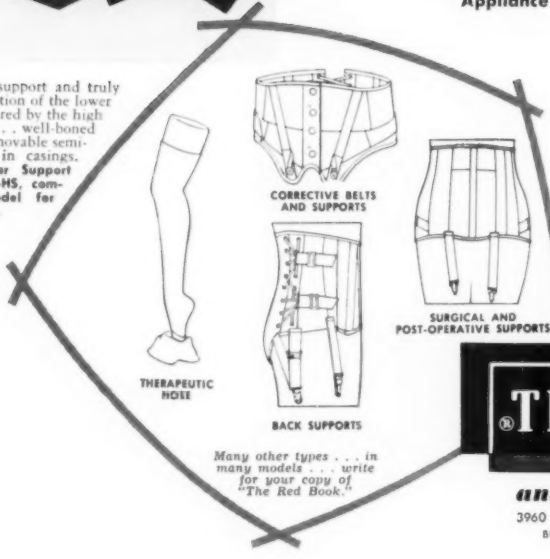
effective FIXATION

Anatomically correct . . . therapeutically sound . . . these principles are designed in, and built in, each Truform appliance.

Effective support or effective fixation . . . this you can depend on when you prescribe "Truform." Your patient benefits from the most careful selection and skillful fitting because . .

- **TRUFORM Anatomical Supports are available only from the Ethical Appliance Dealer**

Very rigid support and truly effective fixation of the lower spine is assured by the high solid back . . . well-boned and with removable semi-rigid stays in casings. **Sacro-Lumbar Support Model 1165-HS, comparable model for men 447-HS.**



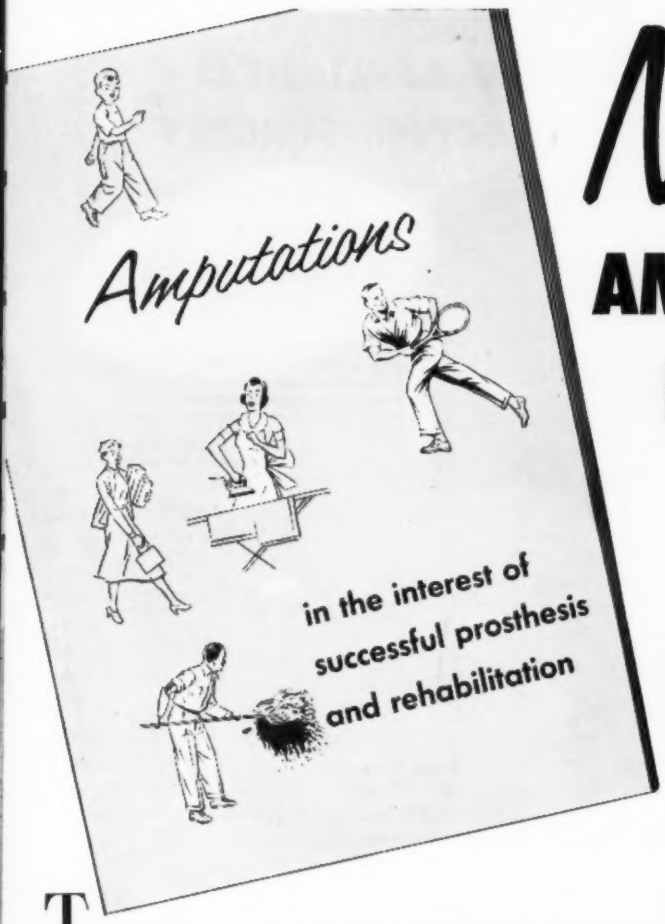
Many other types . . . in many models . . . write for your copy of "The Red Book."

®TRUFORM

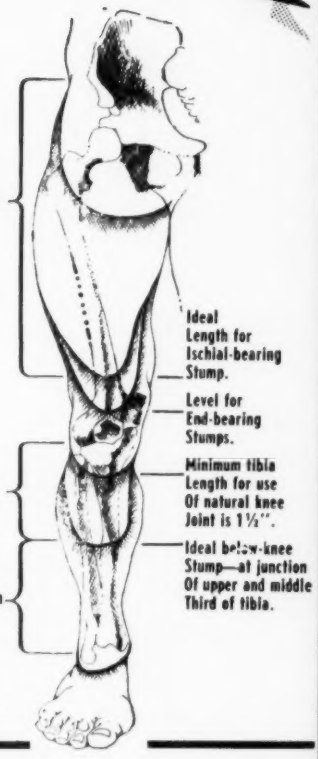
anatomical supports

3960 ROSSLYN DRIVE, CINCINNATI 9, OHIO

BRANCHES: New York and San Francisco



New AMPUTATION BOOKLET



THIS booklet, designed to serve as a concise reference regarding amputations, prostheses and the rehabilitation of the amputee, is now available. It has been written under the supervision of an eminent orthopedic surgeon and incorporates the experience gained by the Hanger organization from supplying prostheses for nearly 100 years. Charts and drawings, showing the sites of election and various prostheses, and information about the care and fitting of the amputee, are presented. We believe you will find this booklet a valuable source of information. Write or phone the Hanger office nearest you for your Copy of the Amputations Booklet.

Hanger PROSTHESIS

AVAILABLE AT AUTHORIZED FACILITIES IN THE FOLLOWING CITIES:

Eastern Region:

BALTIMORE 1, MD.
BOSTON 15, MASS.
CHARLESTON 2, W. VA.
NEW YORK 11, N. Y.
PHILADELPHIA 7, PA.
RALEIGH, N. C.
RICHMOND 19, VA.
ROANOKE 12, VA.
WASHINGTON 13, D. C.

COLUMBUS 8, OHIO
JOHNSTOWN, PA.

Central Region

PITTSBURGH 1, PA.

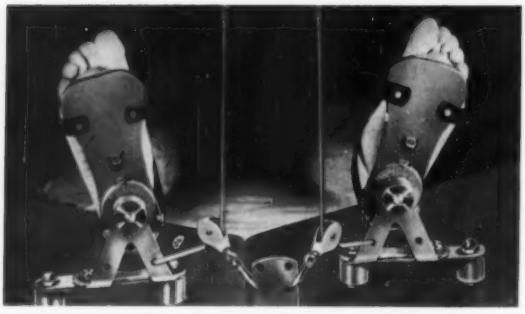
Southeastern Region

ATLANTA 9, GA.
BIRMINGHAM 1, ALA.
COLUMBIA 5, S. C.
JACKSONVILLE, FLA.
MIAMI 37, FLA.
MOBILE, ALA.
MONTGOMERY, ALA.
NASHVILLE 5, TENN.
NEW ORLEANS 19, LA.
ORLANDO, FLA.
SAVANNAH, GA.
TAMPA 2, FLA.
WEST PALM BEACH, FLA.

Midwestern Region:

CHICAGO 5, ILL.
CINCINNATI 29, OHIO
DALLAS 1, TEXAS
EVANSVILLE, IND.
FORT WAYNE, IND.
INDIANAPOLIS 2, IND.
OKLAHOMA CITY 3, OKLA.
PEORIA 4, ILL.
ST. LOUIS 66, MO.
WICHITA, KANS.

BOWEN FRACTURE APPLIANCES— GREAT AIDS TO BETTER SURGERY



LEG EXERCISER SETS

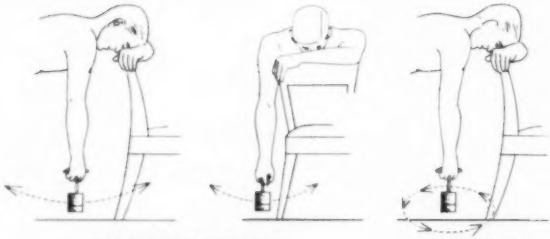
Designed to assist in passive abduction after cup arthroplasty, rehabilitation of paraplegics, and many other cases requiring weight controlled exercises.

- Rigid Construction—Relatively Light in Weight
- Moves Freely on Ball Bearings in All Directions
- Protractor Adjustment for Foot Angle Control
- Weight Attaching Eyes at Different Levels
- Foot and Heel of Exerciser Covered with Foam Rubber
- Exercising Board 14" x 48", Hinged at Center and Angled to Approximate the Arc Scribed by the Legs

ORMANDY PENDULUM EXERCISER

To Prevent Frozen Shoulder

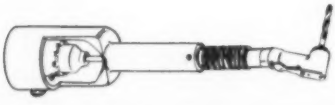
An excellent means to RELIEVE MUSCLE SPASM and PAIN of the shoulder girdle by traction in order to increase the ARC OF MOTION of the scapulo-humeral joint.



Efficient Method of Exercising for Shoulder—Joint Injuries

To Prevent Frozen Shoulder

The compact size of the Pendulum Exerciser will make it possible to increase the arc of motion without hitting the leg of the patient.



ANGLE DRILL ATTACHMENT

For Luck Bone Saw and Stryker Drill

Designed Especially for the Bankhart Operation

Excellent for bone surgery at difficult angles and in restricted areas requiring use of drills, curetting burrs, slotting burrs. Rigidly constructed, light in weight. Entire unit may be sterilized. Two 3/32 inch diameter High Speed Drills supplied with each attachment.

Easily attached to Jacobs chuck with key.

A hole in the end of the drill bit is provided so that the suture can be threaded and pulled through with the extraction of the drill.

GONIOMETER— Pocket Size Anodized Aluminum

A Pocket Size instrument with calculation flexibility allowing complete angle determination in degrees.

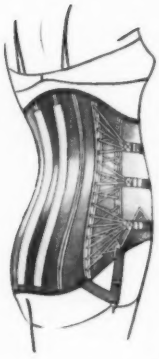
Produced from aluminum, anodized and dyed black, with white-lead-filled dial and indications permitting full penetration of radiation and screening a permanent secondary shadow of measurement on the film for consultations and computations.

BOWEN & COMPANY INC.

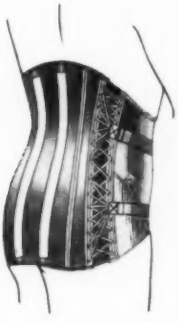
P. O. Box 5818
BETHESDA, MARYLAND

FOR
ORTHOPEDIC
APPLICATIONS

Freeman SURGICAL SUPPORTS



MODEL 423
Sacro-Lumbar Back
Support for Women



MODEL 422
Sacro-Lumbar Back
Support For Men

For 68 years Freeman has worked closely with orthopedic surgeons to design surgical garments that provide *correct* support. Each garment is made by skilled craftsmen using the finest materials available.

There's a quality Freeman support for most every application. You can be certain that the garment you select will carry out your prescription to the best possible satisfaction of you and your patient.

Freeman corset-type back supports provide bracing in any desired degree to almost complete immobilization. Special construction features assure comfort for the wearer in sitting, standing and reclining positions.

FREEMAN QUALITY FEATURES

New Dacron-Pima Cotton Fabric. Petal-Soft Interior Finish cushions the stays, avoids irritation. Self-Smoothing, Exclusive Non-Wrinkle Fly speeds putting on garment and avoids comfort-robbing wrinkles. Soft Plush Padding under hooks and eyes. Superb Needle Work.

Prescribe **FREEMAN** *with Confidence!*

FREEMAN MANUFACTURING CO.
Dept. 704, Sturgis, Michigan
Please send details on new Freeman features and include free reference catalog.

Name_____

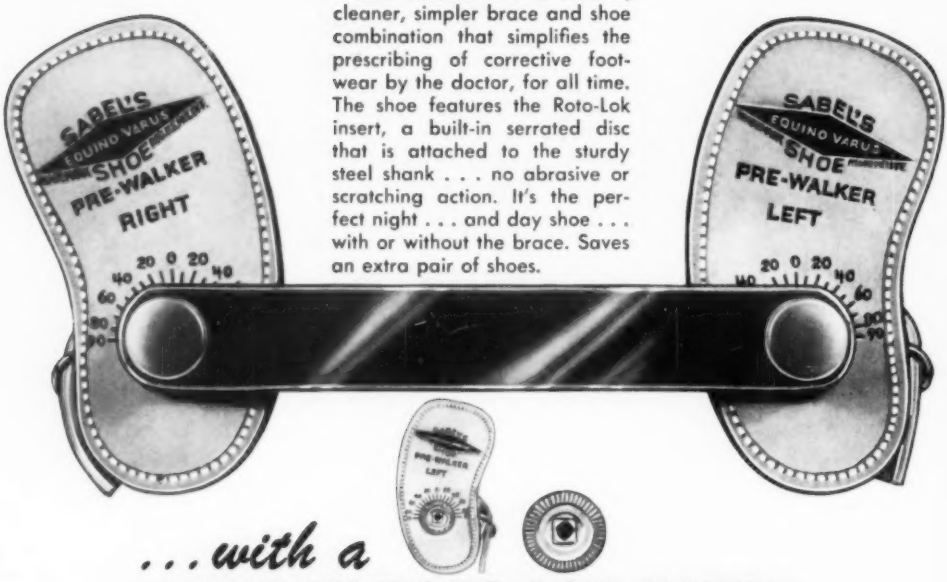
Address_____

City_____ Zone____ State_____

New SABEL'S EQUINO-VARUS
TRADE MARK REG. U.S. PAT. OFF.

CONVERTIBLE
BRACE SHOE

Sabel introduces a newer, cleaner, simpler brace and shoe combination that simplifies the prescribing of corrective footwear by the doctor, for all time. The shoe features the Roto-Lok insert, a built-in serrated disc that is attached to the sturdy steel shank . . . no abrasive or scratching action. It's the perfect night . . . and day shoe . . . with or without the brace. Saves an extra pair of shoes.



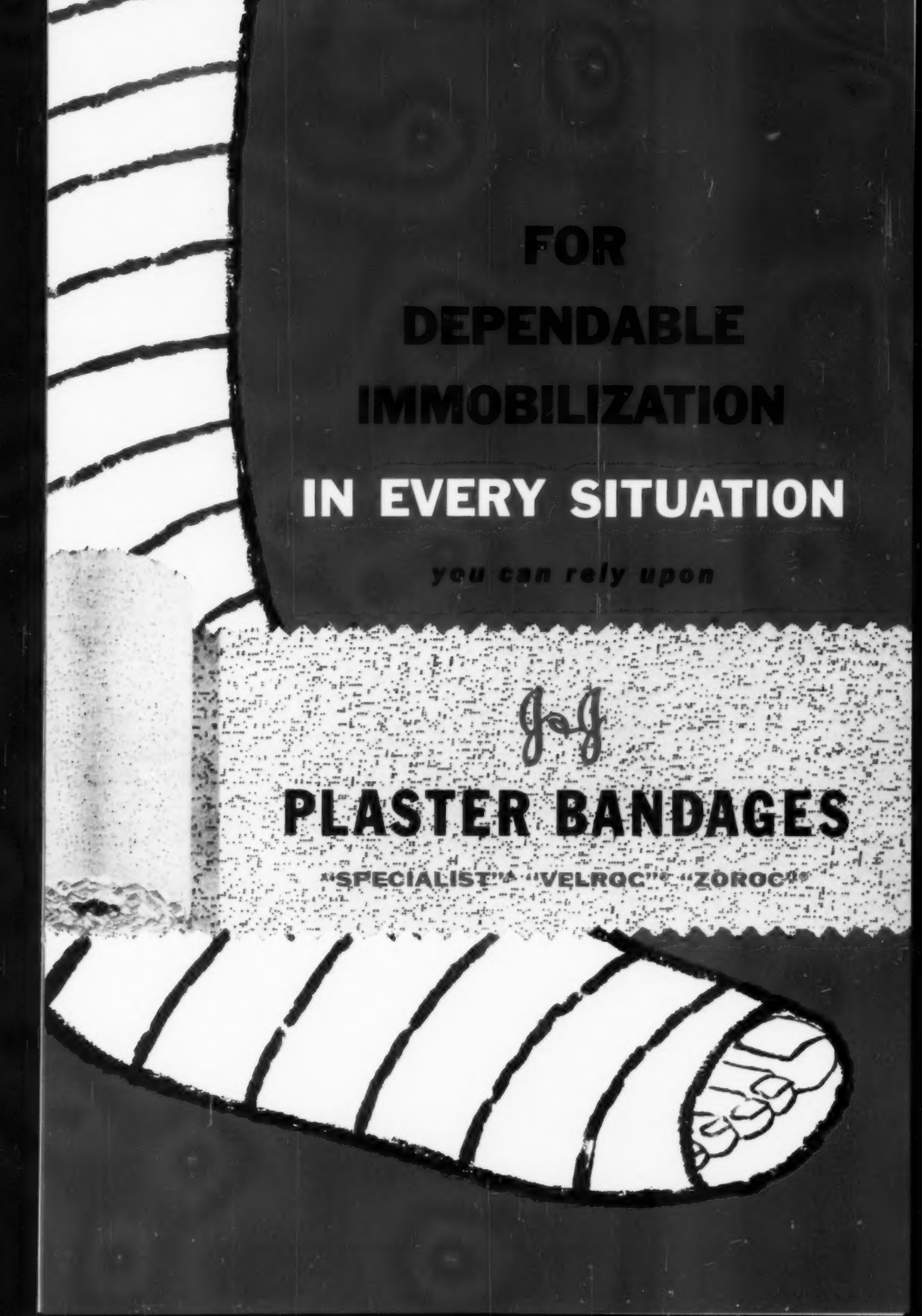
. . . with a
BUILT-IN ROTO-LOK INSERT

The setting of the splint on the shoe is made easy by a protractor that is stamped on the sole of each shoe.

EMBOSSED PROTRACTOR STAMPED ON SOLES

The brace has a matching serrated disc and smooth knurled nut that screws into the disc in the sole of the shoe, holding it firmly in the position the doctor desires.
This smoother brace has no protruding arms or edges to cut or tear bed clothing.

R. J. POTVIN SHOE CO., BROCKTON, MASS.


FOR
DEPENDABLE
IMMOBILIZATION
IN EVERY SITUATION
you can rely upon
J&J
PLASTER BANDAGES
"SPECIALIST" "VELROC" "ZOROC"

FOUR

For Your

1

Specialist® EXTRA-FAST
For club-foot, fore-arm and other casts where rapid setting-time and creamy texture are desired. Supplied in seven sizes.

Specialist® SPLINTS
FAST and EXTRA-FAST. Ready-cut lengths of SPECIALIST bandage for splinting and cast-reinforcement. Save time, work, material—provide added strength where needed. Extra-fast type supplied in 3″ x 15″ and 4″ x 15″ sizes—fast setting type in 3″ x 15″, 4″ x 15″, 5″ x 30″, and 5″ x 45″ sizes.

TYPES

Selection

2

Specialist® FAST-SETTING
The most widely used bandage for all types of casts. Affords more working time for molding before plaster sets. Supplied in six sizes.

3

VELROC® EXTRA FAST
Velvet smooth texture and extremely fast setting-time. Smooth cut, non-ravelling edges and improved cores that will not fall out. Ideal for casts where ease of application and removal, speed of setting, and polished appearance are important. Supplied in four sizes.

ZOROC® RESIN-PLASTER
A resin-reinforced plaster bandage especially useful for walking-boots, long-term casts and wherever maximal strength, minimal weight and effective moisture-resistance are vital. Supplied in five sizes.

4

Johnson & Johnson

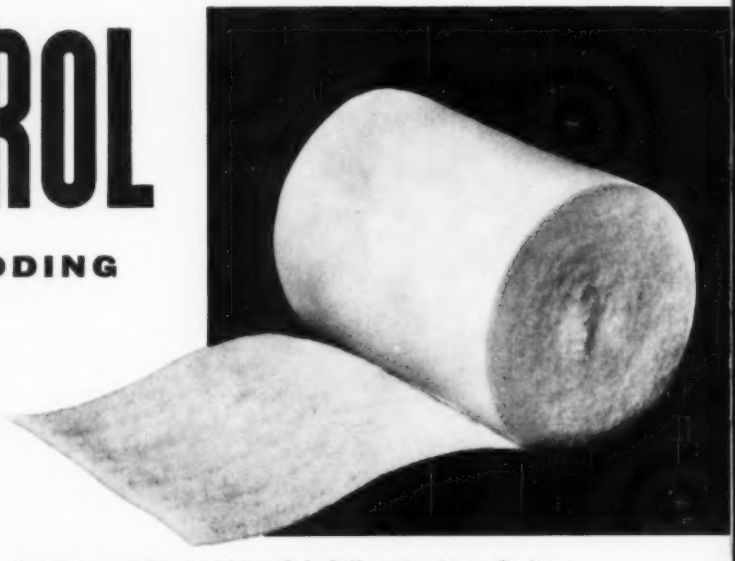
HELPING THE HANDS THAT HEAL

Announcing

SOF-ROL

TRADEMARK

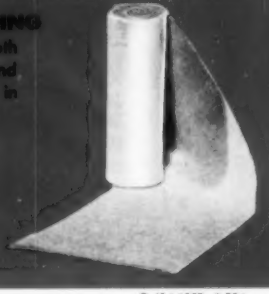
CAST PADDING



A new, improved cast-padding. Soft, fluffy and cushiony. Conforms to body contours without wrinkling. Clings to itself—will not slip during application. Forms a smooth, absorbent protective padding under cast or splint. Unaffected by autoclaving. Supplied in four sizes.

BELLEVIEW® SURGICAL WADDING
Soft, protective cotton, glazed on both sides to provide tensile strength and prevent matting or lumping. Supplied in five sizes.

Specialist® ORTHOPEDIC STOCKINET
Made of soft, knitted cotton. Conforms comfortably to arm, leg or torso. Dispensing boxes keep stockinet clean and dust-free. Supplied in seven sizes.



© J&J 1959 P-226

Johnson & Johnson

VOL. 41-A, NO. 3 APRIL 1959

The Journal of
Bone and Joint Surgery

American Volume

Metabolic Studies in Orthopaedic Patients*†

BY GEORGE E. SPENCER, JR., M.D., HARVEY KRIEGER, M.D., WILLIAM E. ABBOTT, M.D., AND STANLEY LEVEY, PH.D., CLEVELAND, OHIO

From University Hospitals of Cleveland and Western Reserve University School of Medicine, Cleveland

During the past five years, we have carried out metabolic balance studies [1] on surgical patients admitted to the Metabolic Division of University Hospitals in order to understand the biochemical alterations that occur following operation or injury. Recently, similar studies have been made of patients with fractures or who have undergone various orthopaedic procedures so we could determine if, and to what extent, the metabolic alterations following trauma to bone differed from trauma to soft tissue.

Cuthbertson [2] reported the results of balance studies made of patients having fractures and found that following injury there was a marked loss of nitrogen, phosphorus, and sulphur. He noted that the maximum loss occurred from the second to the sixth day after injury and then gradually declined with a slight but continuous loss which sometimes lasted up to two months. He concluded that the material undergoing catabolism was derived mainly from muscle. From later studies [3], he concluded that the maximum daily nitrogen deficit may be as much as twenty-three grams and one of the patients he studied had a nitrogen deficit amounting to 137 grams in ten days which would represent approximately 1.7 kilograms of muscle tissue or 7.7 per cent of the total body nitrogen. Cuthbertson [4] was unable to maintain nitrogen equilibrium in such patients but noted that the weight loss and nitrogen wasting could be minimized by increasing the protein and caloric intake. In six patients with fractures involving the lower extremity, Howard reported an average loss of 220 grams of nitrogen which is equivalent to almost 1,400 grams of protein. The greatest loss occurred on the sixth day and nitrogen equilibrium was not reached usually until the thirty-sixth day. He did not recommend excessive feeding since he believed it would not overcome the nitrogen deficit. Moore and his associates stated that the duration and magnitude of negative nitrogen balance correlated closely with the extent of the trauma. They reported that the metabolic alterations which occur in a patient with a fracture of the shaft of the femur are comparable with those seen in an individual who has a third-degree burn.

* Read in part at the Annual Meeting of the Orthopaedic Research Society, New York, N. Y., February 1, 1958.

† This work was supported in part by grants from the National Institutes of Health, United States Public Health Service A-760 (C5), the John A. Hartford Foundation, the Upjohn Co., Kalamazoo, Michigan, and Mead Johnson and Co., Evansville, Indiana.

Our objective has been to study nutritionally normal patients who sustained a fracture or who were to undergo a major orthopaedic procedure. Specifically, we hoped to clarify which factors were of primary importance in the metabolic response to bone trauma and in what way the nutritional regimen could influence metabolic alterations.

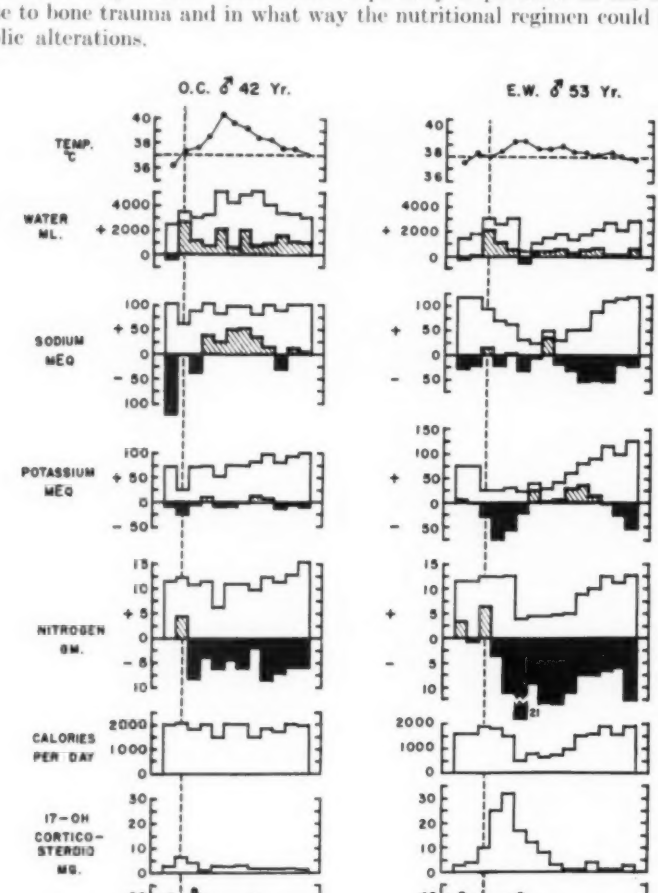


FIG. 1

Patients O. C. and E. W. The intake, output, and the balance are recorded on the ordinate and the time on the abscissa. The intake is represented by the height of the column above the horizontal zero line and the output is plotted downward from the top of the intake column. Negative balance is indicated by the extent of the black area below the zero line and the cross-hatched area above the zero line represents a positive balance. Each column represents a twenty-four-hour period. The bottom graph indicates the nitrogen and caloric intakes per kilogram of body weight. The vertical dotted line indicates the day of operation.

METHODS

With the use of metabolic balance techniques studies were made of six patients who had bone trauma. The patients were placed on a diet which they would consume and which the dietitian considered to be adequate. Before consumption, all the food was analyzed for nitrogen, sodium, and potassium and was prepared and weighed by the staff of the Metabolic Division. Any residual food not taken by the patient was analyzed in the laboratory. All excreta including urine, faeces, vomit, and sputum were collected and analyzed for sodium, potassium, and nitrogen. The techniques for collection, measurement, and the chemical analysis employed have been previously reported in detail [1]. The patient's total intake of water and nutrients was given intravenously on the day of operation. In some instances, the oral intake was supplemented by intravenous alimentation for one or two days following operation. Since the amount of blood given at the time of operation was essentially comparable with the amount lost, it was not included in the balance data. The patients undergoing elective surgery were studied preoperatively for two to ten days and postoperative studies were continued for ten to fifteen days. Postoperatively, the patients' diets were increased if they desired more food, but no attempt was made at forcible feeding. The patients were weighed daily at 6:30 A.M., after voiding and before eating. The daily excretion of 17-hydroxycorticosteroids in the urine was measured in each patient to indicate adrenal cortical activity.

RESULTS

Figures 1 (O. C. and E. W.) and 2 (F. G. and M. T.) show the data obtained from the study of two men and two women. O. C., a white man, forty-two years old, was in excellent nutritional status and had a lumbosacral fusion with an autogenous iliac graft performed for instability of the lumbosacral spine. He was then kept in bed without a cast. His postoperative course was complicated by cystitis with fever ranging up to 40.2 degrees centigrade for six days. He received no parenteral fluids after the day of operation. This patient showed a positive water balance which we estimated to be similar in amount to his insensible loss. He retained sodium from the second through the sixth day and then was in balance. His potassium balance showed minimal fluctuation. For the ten days he was studied, the patient was in negative nitrogen balance and had a cumulative deficit of 61.8 grams. His daily nitrogen intake was 0.15 gram per kilogram of body weight. His daily caloric intake was relatively constant, ranging around 2,000, which equalled approximately twenty-five calories per kilogram of body weight.

O. C. showed little increase in the urinary 17-hydroxycorticosteroids in relation to the degree of trauma and fever. While we have no explanation for this, we have noted such a response occasionally in other patients who showed no evidence of adrenal cortical insufficiency. This patient lost four kilograms or approximately nine pounds in ten days.

E. W., a white man fifty-three years old, underwent arthrodesis of the right hip for osteo-arthritis. He appeared well nourished. Following surgery, he was kept in bed in a double hip spica. There was a mild febrile response for two days after arthrodesis. He was maintained on intravenous alimentation for two days postoperatively and then was given food by mouth. The patient was in a state of negative water balance as his insensible loss would offset his minimal recorded gain and, except for one day, was also in negative sodium balance. His potassium balance showed a deficit for three days postoperatively, then a slight gain for six days, and then a loss. There was a large daily nitrogen deficit throughout the postoperative study period. For the first five days postoperatively, his cumulative nitrogen deficit was 54.6 grams. His caloric and nitrogen intakes were poor and larger deficits occurred when the intakes decreased. On the other hand, the urinary 17-hydroxycorticosteroids were significantly increased on the

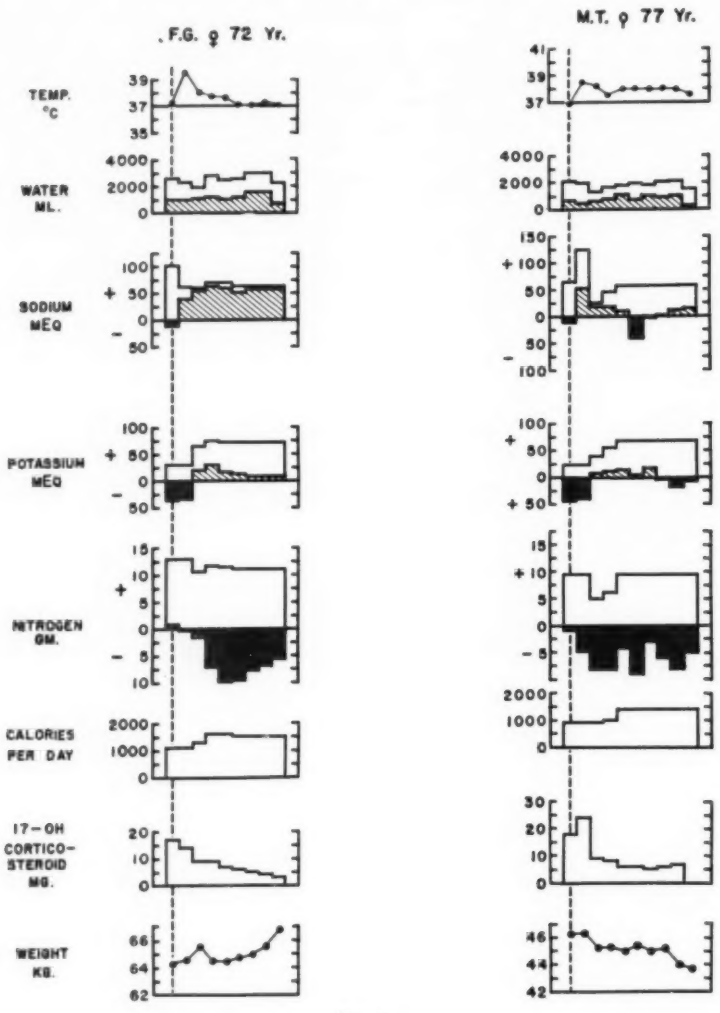


FIG. 2

Patients F. G. and M. T. The studies are plotted as in Fig. 1. The positive balance is represented by the height of the cross-hatched area above the zero line and the deficit by the extent of the black column below the zero line.

first and second postoperative days but gradually returned to normal values. It should be noted (Fig. 1) that there is no correlation between the nitrogen deficit and urinary 17-hydroxycorticosteroid excretion in this patient. He had a four-kilogram weight loss in twelve days.

At the bottom of Figure 1, the data of the dietary intakes of patients O. C. and E. W. are recorded on a per kilogram of body weight basis. From this information, one is readily able to compare one patient with another. The positive nitrogen balance is shown by the hatched area above the zero line and the negative balance by the extent of the black column below the zero line. Both of the patients whose data are shown in Figure 1 had a poor caloric and nitrogen intake. On the third postoperative day, E. W.'s caloric intake was under 700 calories which obviously is quite inadequate. This patient's cumulative nitrogen deficit for the first twelve postoperative days amounted to 119 grams of nitrogen.

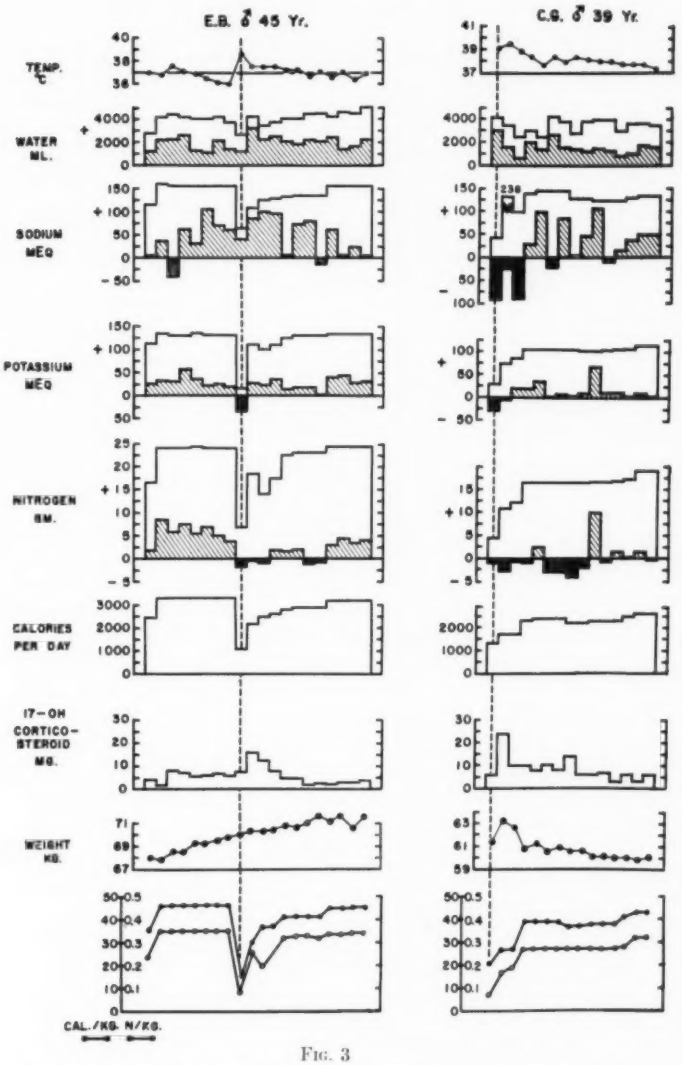


FIG. 3

Patients E. B. and C. G. Positive balance is represented by the height of the cross-hatched columns and the deficit by the extent of the black columns below the zero line. The bottom graph compares the nitrogen and caloric intakes per kilogram of body weight.

F. G. (Fig. 2), a white woman seventy-two years old, had an immediate insertion of an Austin Moore prosthesis for a fracture of the left femoral neck. She was not walking but was active in bed. She had a febrile reaction for one day and was in a negative state of potassium balance for one day postoperatively. Her water balance was on the positive side with a gain in sodium and body weight. The cumulative five-day negative nitrogen balance was 27.7 grams. During this time, her daily nitrogen and caloric intakes averaged 0.18 gram and twenty-three calories per kilogram of body weight, respectively. It should also be noted that her 17-hydroxycorticosteroid response was elevated on the day of operation

and gradually fell to normal values. She showed a two-kilogram weight gain at the end of the studies.

M. T. (Fig. 2), a white woman seventy-seven years old, also had an immediate insertion of an Austin Moore prosthesis for a fracture of the femoral neck. Postoperatively she exhibited a two-day febrile response. Her water, sodium, and potassium balances fluctuated above and below the zero line without any definite pattern. She remained in negative nitrogen balance for the nine days she was studied and had a cumulative nitrogen deficit of 33.8 grams for the first five postoperative days. Her daily nitrogen and caloric intakes per kilogram of body weight averaged 0.20 gram and twenty-eight calories, respectively. Postoperatively, her urinary 17-hydroxycorticosteroids increased and she lost two kilograms of weight in nine days.

Figure 3 shows the data obtained from the study of two patients (E. B. and C. G.) who had adequate caloric and nitrogen intakes during the postoperative period. E. B., a white man forty-five years old, had an Austin Moore prosthesis inserted for avascular necrosis of the right femoral head secondary to a fracture of the femoral neck. Study for eight days preoperatively and eleven days postoperatively showed that he maintained a positive water balance, if the estimated insensible loss is subtracted from his recorded balance. He also retained sodium which gradually returned to equilibrium. He maintained a positive potassium balance throughout the study except on the day of operation when the intake was very low. The average daily nitrogen and caloric intakes per kilogram of body weight were 0.34 gram and forty-three calories, respectively. He exhibited a positive nitrogen balance during the preoperative period. Although postoperatively he exhibited five days of slight nitrogen deficit and three days of positive balance, his nitrogen and caloric intakes were less during these days than preoperatively and during the last four days of study. The patient gained weight following the operation.

C. G. (Fig. 3), a Negro man thirty-nine years old, was treated for a simple fracture of the shaft of the tibia with immediate intramedullary fixation and cast and was permitted daily sitting in a chair. The patient had been on an alcoholic debauch at the time of injury. He maintained his water balance in approximate equilibrium with somewhat erratic sodium balance which remained on the positive side. The potassium balance was slightly positive. He had cumulative nitrogen deficit of 3.6 grams during the first five days after operation and was in positive balance after the eighth day. The nitrogen intake was approximately 0.27 gram and the caloric intake approximated thirty-seven calories per kilogram of body weight daily. Postoperatively both E. B. and C. G. exhibited the usual increase in the urinary 17-hydroxycorticosteroids.

The bottom of Figure 3 (E. B. and C. G.) shows the caloric and nitrogen intakes which are recorded on a per kilogram of body weight basis. The caloric and nitrogen intake ranged between thirty-five and forty-five calories and about 0.3 gram of nitrogen per day for each of these two patients.

DISCUSSION

It should be emphasized that these patients were selected at random and were considered to be average patients. They were permitted to advance their diet as desired and were not forcibly fed. Most of the patients were able to maintain their electrolyte and water balance in approximate equilibrium when on oral intake. E. W. (Fig. 1) was unable to maintain his water balance and lost sodium and potassium. F. G. retained sodium and water and, because of this, gained weight in spite of a negative nitrogen balance.

Four of the six patients were in negative nitrogen balance following injury or operation. These four patients were unable to consume what is considered adequate nitrogen and caloric intake for patients undergoing major surgery. The National Research Council recommends that minimal requirements per day for a

resting or moderately inactive person are one gram of protein or 0.16 gram of nitrogen and twenty-five calories per kilogram of body weight. Such a nutritional intake should keep one in nitrogen balance or equilibrium. Rhoads stated that, following major trauma, a patient should be given 0.3 to 0.4 gram of nitrogen and thirty to forty calories per kilogram of body weight per day to prevent protein wasting and a loss of body weight. This is almost twice the amount a resting individual not exposed to surgery requires and would equal an intake of from 130 to 175 grams of protein and 2,100 to 2,800 calories for a seventy-kilogram or 154-pound patient. Patients (Fig. 3) E. B. and C. G. were the only ones who maintained this level.

None of our patients undergoing surgery showed potassium balance which paralleled the nitrogen balance in a consistent ratio of three milliequivalents of potassium to one gram of nitrogen. This ratio was previously reported in starvation states and has not been found in post-traumatic or postsurgical studies [1,7]. The potassium deficit is usually quite large for two or three days following trauma and then this ion is conserved. We can account for this deviation from the potassium-nitrogen ratio in that the potassium is not all coming from the breakdown of muscle but is also being mobilized from the cells and later, being replaced intracellularly.

The insensible water loss was not measured in these patients but if 800 to 1,000 milliliters per day were allowed their water balance would have only modest fluctuations from equilibrium.

Immobilization alone was shown by Deitrick, Whedon, and Shorr to cause only minor fluctuation in nitrogen balance. One of their subjects showed nitrogen losses of 2.5 and 1.5 grams per day during two weeks of a seven-week period of immobilization. During the other five weeks there were minimal fluctuations between equilibrium and slight, positive nitrogen balance.

SUMMARY AND CONCLUSIONS

1. The four patients who underwent orthopaedic procedures were in negative nitrogen balance well below the dietary levels recommended by Rhoads, while the two patients who maintained a high nitrogen and caloric intake per kilogram of body weight were either in positive nitrogen balance or showed transient and minimal nitrogen deficits. It is of interest to note that, with the exception of F. G. (Fig. 2), all the patients showed fluctuations in weight and nitrogen balance that fairly well paralleled their dietary intake.

2. There was no correlation between the nitrogen deficits and the urinary excretion of 17-hydroxycorticosteroids.

3. It therefore appears from these studies that factors other than trauma to bone and adrenal overactivity are of major importance in governing the patient's metabolic response. The factors which must be considered are: nutritional intake, fever, immobilization, and the preoperative nutritional status of the patient.

REFERENCES

1. Abbott, W. E.; Krieger, Harvey; Babb, L. I.; Levey, Stanley; and Holden, W. D.: Metabolic Alterations in Surgical Patients. I. The Effect of Altering the Electrolyte, Carbohydrate and Amino Acid Intake. Ann. Surg., **138**: 434-452, 1953.
2. Cuthbertson, D. P.: The Disturbance of Metabolism Produced by Bony and Non-Bony Injury, with Notes on Certain Abnormal Conditions of Bone. Biochem. J., **24**: 1244-1263, 1930.
3. Cuthbertson, D. P.: Observations on the Disturbance of Metabolism Produced by Injury to the Limbs. Quart. J. Med., **1**: 233-246, 1932.
4. Cuthbertson, D. P.: Further Observations on the Disturbances of Metabolism Caused by Injury, with Particular Reference to the Dietary Requirements of Fracture Cases. British J. Surg., **23**: 505-520, 1935.
5. Deitrick, J. E.; Whedon, G. D.; and Shorr, E.: Effects of Immobilization upon Various Metabolic and Physiologic Functions of Normal Men. Am. J. Med., **4**: 3-36, 1948.
6. Howard, J. E.: Metabolic Observations on Patients Convalescent from Fracture. Trans. Assn. Am. Phys., **58**: 162-170, 1944.

7. Moore, F. D.; Steenburg, R. W.; Ball, M. R.; Wilson, G. M.; and Myrden, J. A.: Studies in Surgical Endocrinology. I. The Urinary Excretion of 17-hydroxycorticoids, and Associated Metabolic Changes, in Cases of Soft Tissue Trauma of Varying Severity and in Bone Trauma. Ann. Surg., **141**: 145-174, 1955.
8. Rhoads, J. E.: Collective Review. Protein Nutrition in Surgical Patients. Internat. Abstr. Surg., **94**: 417-427, 1952.

Posterolateral Bone-Grafting for Fusion of the Lumbar and Lumbosacral Spine*

BY MELVIN BRENT WATKINS, M.D., NEW YORK, N. Y.

From the New York Orthopaedic Dispensary and Hospital, Columbia-Presbyterian Medical Center, New York

Operative fusion of the posterolateral vertebral elements [6,7] following attempts at posterior fusion in patients with pseudarthrosis or defective neural arches at the lower lumbar and lumbosacral levels may be accomplished in a high proportion of cases.

The posterolateral approach [6,11] to the lumbosacral spine for fusion consistently has proved to be satisfactory in my experience, providing ready access to the transverse processes, posterior articulations, and pedicles without disturbing tissues previously operated upon. It is also preferable to the mid-line approach used in correction of congenital and postsurgical laminal defects or in patients with tuberculosis involving the posterior elements of the spine.

OPERATIVE TECHNIQUE

The operative technique has been modified as follows. The iliac attachment of the muscles of the spine is released with an osteotome and a thin layer of ilium is included to ease closure. Securing the muscles of the spine over the seated graft with a few deep sutures has obviated screw fixation in most instances. More complete details of the procedure are described in an article which appeared in 1953 [11].

Twenty-eight patients who had posterolateral spine fusion by this technique have been evaluated (Table I). Previous operations on the lower portion of the back had been performed on twenty-one patients. Of the seven primary fusions, five were performed for spondylolisthesis, one for congenital defects of the lamina, and one for tuberculosis of the posterior elements of the spine.

Seventeen bilateral and eleven unilateral procedures were performed. Autogenous iliac bone was used in all patients; supplementary grafts of bone-bank bone were required in six. The essential steps of the procedure are:

* Read at the Annual Meeting of The American Academy of Orthopaedic Surgeons, Chicago, Illinois, January 28, 1957.

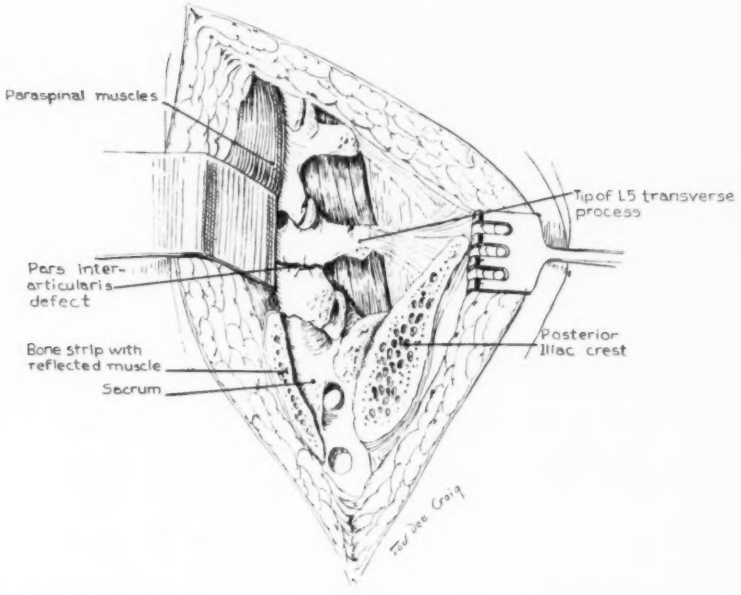


FIG. 1

Exposed area of the lumbosacral spine for either a one or two-joint fusion in a patient with spondylolisthesis.

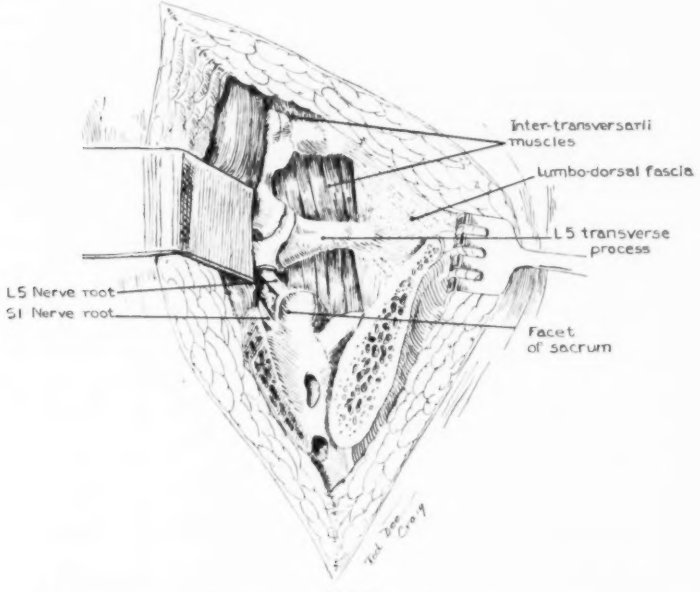


FIG. 2

The inferior facet of the fifth lumbar vertebra has been removed to reveal the underlying nerve roots.

1. A longitudinal incision beginning at the lateral border of the erector spinae muscles is curved medially at the distal end to allow access to the posterior iliac crest. If preferred, a U-shaped incision may be used for bilateral procedures.

TABLE I

Case	Sex and Age (*Years*)	Operative Indications	No. of Previous Low-Back Operations	Vertebrae Fused Unilateral	Vertebrae Fused Bilateral	Length of Follow-up (*Years*)	Results of Fusion
1	F 32	Pseudarthrosis	4	L4-L5		8	Solid
2	F 48	Pseudarthrosis	5	L5-S1		7	Failure
3	F 52	Pseudarthrosis	4	L4-S1		7	Solid
4	M 28	Pseudarthrosis	4	L4-S1		7	Solid
5	M 26	Pseudarthrosis	5	L4-S1		6½	Failure; solid, L4-L5, motion, L5-S1
6	F 27	Post-laminectomy instability	3		L4-S1	7½	Failure; minimal motion at L4-L5 and L5-S1
7	F 26	Post-laminectomy instability	4	L4-S1		5	Solid
8	F 25	Tuberculosis of posterior elements	None	L4-S1		6½	Solid
9	F 22	Spina bifida	None		L4-S1	5½	Solid
10	F 40	Pseudarthrosis	3		L4-S1	5	Solid
11	F 35	Post-laminectomy instability	1		L4-S1	4	Solid
12	F 32	Post-laminectomy instability	3		L4-S1	4	Solid
13	F 34	Pseudarthrosis	2	L4-S1		2	Failure
14	F 36	Post-laminectomy instability	2	L4-S1		2	Failure; minimal motion
15	F 40	Spondylolisthesis at L5	None		L5-S1	3	Solid
16	M 40	Pseudarthrosis	3	L3-S1		3	Failure; motion in all joints
17	F 44	Spondylolisthesis at L5	None		L5-S1	2½	Solid
18	M 41	Pseudarthrosis	2		L4-S1	2½	Failure; questionable motion at L4-L5 and L5-S1
19	F 44	Post-laminectomy instability	2	L4-S1		3	Failure at L4-L5; repair and fusion of opposite side 9 mos. later; solid at final examination
20	M 25	Pseudarthrosis	3		L5-S1	2½	Solid
21	M 21	Pseudarthrosis	2		L4-L5	2	Solid
22	F 45	Pseudarthrosis	2		L4-S1	2	Solid
23	M 30	Pseudarthrosis	2		L4-L5	2	Solid
24	M 41	Spondylolisthesis at L5	None		L4-S1	1½	Solid
25	F 48	Pseudarthrosis	1		L3-S1	2	Solid
26	M 33	Spondylolisthesis at L4 and L5	None		L4-S1	2	Solid
27	F 29	Pseudarthrosis	10		L4-L5	1½	Failure
28	M 35	Spondylolisthesis at L5	None		L4-S1	1	Solid

TABLE I

Roentgenographic Evaluation	Clinical Evaluation		Postoperative Resumption Activities
	Preoperatively	Postoperatively	
Biplane bending	Limited housework; restricted bending and lifting	Full housework	6 mos.
Biplane bending	Minimal housework	Minimal housework	4 mos.
Biplane bending	Incapacitated for housework	Full housework; avoids heavy lifting	6 mos.
Biplane bending	Hospitalized bed patient (tuberculosis) 1½ yrs.	Watch-dial painter	6 mos.
Biplane bending	Hospitalized bed patient (tuberculosis) 1 yr., 3 mos.	Sedentary work	7 mos.
Biplane bending	Minimal housework; no sports	Full activity including sports	6 mos.
Biplane bending	Hospital patient; semi-bed, 6 wks.	Part-time librarian	6 mos.
Biplane bending also exploration at time of sacro-iliac fusion	Full activity until 3 mos. preoperatively	Sacro-iliac fusion; drainage abscess of thigh during 2-year period; full activity	2½ yrs.
Lateral, flexion, and extension	Activities limited; gave up tennis	Full activity including tennis	6 mos.
Biplane bending	Unable to work as dental assistant	Part-time dental assistant; (cancer of the cervix)	1 yr.
Biplane bending	Limited housework; no lifting	Full housework	6 mos.
Lateral, flexion, and extension	Confined to house; minimal activity 4 to 6 hours a day	Full activity	6 mos.
Biplane bending	Totally disabled (nurse)	Unimproved; transferred to another hospital	
Lateral	Totally disabled (nurse)	Part-time nursing	
Biplane bending	Limited housework; no lifting	Full activity	1 yr.
Biplane bending	Sedentary activities; no bending or lifting	No change in preoperative condition	4 mos.
Biplane bending	Limited housework; no lifting	Full activity	5 mos.
Biplane bending	Totally disabled; compensation	Disabled for heavy work; sedentary employment unavailable	
Lateral, flexion, and extension	Totally disabled teacher	Full-time teaching	1 yr. after bilateral fusion
Lateral, flexion, and extension	Totally disabled traveling salesman	Full-time salesman	6 mos.
Biplane bending	Totally disabled store clerk	Full activity; airline reservation clerk	5 mos.
Lateral, flexion, and extension	Unable to work as nurses' aide; minimal housework	Full housework; avoids heavy lifting	6 mos.
Biplane bending	Totally disabled merchant seaman	Full activity as merchant seaman	8 mos.
Biplane bending	Totally disabled factory worker, compensation	Full activity at usual job	6 mos.
Biplane bending	Totally disabled fitter in dress shop	Full-time fitter in dress shop	7 mos.
Lateral	Totally disabled truck driver	Disqualified as truck driver; other work unavailable	
Biplane bending	Moderate housework	Moderate housework	6 mos.
Biplane bending	Totally disabled mail carrier	Part-time, inside employment at post office	8 mos.

2. The broad expanse of the muscle attachment to the ilium is released with an osteotome and a thin layer of bone included. This modification in the original technique prevents fraying of the muscle fibers and facilitates closure of the wound.

3. Exposure of the posterior articulations, pars interarticularis, and transverse processes is accomplished by reflecting the muscle mass toward the mid-line.

4. The fusion bed is prepared by excising soft tissue and turning up chips of bone from available sources.

5. Single or multiple grafts are removed from the iliac crest and positioned in the fusion bed. A single large graft, if insecure, may be fixed with one or two screws. In most cases the graft fits snugly and is held in place by a few well placed sutures in the overlying muscle mass.

6. The erector spinae muscles are reattached to the gluteal fascia and the wound is closed.

In spondylolisthesis, with little or no displacement, one-joint fusion may be adequate. There are two such cases in this series, the fifth lumbar vertebra having been fused to the sacrum in each.

POSTOPERATIVE MANAGEMENT

In ten patients the average period of postoperative recumbency was eight weeks. In two, a plaster spica was used; and in eight, a brace or reinforced corset was applied for postoperative immobilization. Walking was allowed gradually with a brace or corset for support. Eighteen of the patients operated upon walked three to four weeks after surgery supported by a brace or corset.

RESULTS

Except for exploration, I believe there is no method by which solid spine fusion can be determined with certainty. Since this method is not practicable as a routine procedure, one must rely on clinical findings and the interpretation of roentgenograms in evaluating results of fusion. In three patients who had unilateral procedures in this group, it was possible to determine the status of the fusion by exploration at the time of a second operative procedure. In one patient who had been operated upon for tuberculosis of the fifth lumbar vertebra and sacrum, tuberculosis of the sacro-iliac joint developed fourteen months after operation. At the time of fusion of the sacro-iliac joint, the site of the spine graft was explored and found to be solidly fused. The fusion sites of the other two patients operated upon for lumbosacral instability following laminectomy were explored because of persistent low-back pain. In one patient, fusion was solid and in the other fusion had not occurred. In each patient, grafts were implanted in the opposite posterolateral portion of the spine.

The results of fusion were based on biplane bending roentgenograms in twenty-one patients and lateral flexion-extension roentgenograms in seven. Routine oblique roentgenograms were helpful in determining the position of the grafts in relation to the transverse processes.

The clinical results in this series of patients with predominantly multiple operations were recorded on the basis of a comparison of the patient's physical capabilities before and after operation.

Two patients who had unilateral procedures with failure of fusion were reoperated upon. One patient (Case 19, Table I) resumed her usual occupation one year after fusion of the opposite side of the spine. The other patient went to another hospital for operation and was lost to follow-up.

COMPLICATIONS

In this series one patient had wound infection. Postoperative hematomata were aspirated in six cases. In one patient who had a unilateral procedure, reoperation for a displaced graft was performed ten days postoperatively. Postopera-

FIG. 3

FIG. 4

Fig. 3: Bilateral fusion for instability of the spine following laminectomy. Fusion was evaluated by lateral roentgenograms made in flexion and extension.

Fig. 4: Bilateral fusion performed for congenital defects of the lumbosacral spine. Evaluation of fusion was based on biplane bending roentgenograms.

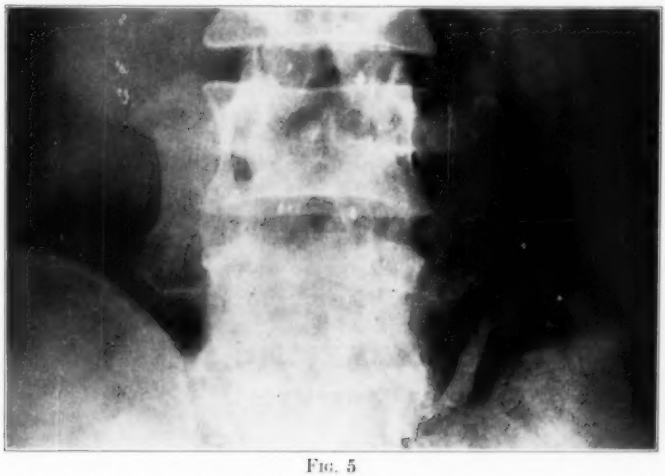


FIG. 5

Bilateral fusion performed for pseudarthrosis at the fourth and fifth lumbar level. Evaluation of fusion was based on biplane bending roentgenograms.

tive ileus developed in two patients but subsided in each without requiring intubation.

DISCUSSION

Although few reports on the technique of exposure of this area of the spine have been published, other surgeons have utilized the posterolateral elements of the spine, usually by dissecting laterally from the mid-line. Hibbs, in 1924, in describing the technique for fusion of the spine in the dorsal area in scoliosis stated: "The dissection is carried farther and farther forward upon each vertebra in turn, until the spinous processes, the posterior surfaces of the laminae, and the base of the transverse processes are bared, thereby exposing the ligamentum subflavum attached to the margins of the laminae and the articulations of the

lateral processes." Hibbs undoubtedly made use of all the exposed bone surface in preparing the fusion bed.

In 1939, Campbell described a method of exposure and utilization of the posterolateral region of the lumbosacral spine in conjunction with fusion of the sacro-iliac joint. He stated that following extra-articular fusion of the sacro-iliac joint, the inner flap of the incision should be dissected up and the posterior aspect of the laminae and transverse processes of the fourth and fifth lumbar vertebrae isolated and denuded. An osseous graft from the crest of the ilium should then be placed in the gutter for the sacro-iliac fusion and extended upward to approximate the denuded surfaces of the fourth and fifth lumbar vertebrae.

This technique, which was unknown to the author in 1953 when a preliminary report on posterolateral fusion of the lumbar and lumbosacral spine was published, is similar to the method of exposure and application of a massive iliac graft described in this report. I am not aware of additional reports of this technique of stabilizing the lumbosacral spine without sacro-iliac fusion.

In 1948, Cleveland, Bosworth, and Thompson described the use of grafts placed along the base of the transverse processes and against the posterior articulations in a method of repairing pseudarthrosis in the lumbosacral spine. In describing the procedure the authors stated: "It consists essentially in denuding the laminae and the lateral margins of the articular processes, with extension of the dissection to the bases of the transverse processes on one side only (hemifusion). The medial portion of the transverse process is likewise denuded. . . . Furthermore, contact is made with the transverse processes and the outer surfaces of the articular facets, as well as across the previous spine fusion on one side." The posterolateral portion of the spine was exposed on one side, leaving the scar tissue intact on the other side to provide stability. Bosworth again reported this method of repair for pseudarthrosis in 1948 [3].

Bosworth and Levine utilized the posterolateral portion of the spine in fusion for tuberculosis, and applied cancellous-bone grafts to the posterior surfaces of the transverse processes and pedicles.

Adkins reported the use of intertransverse tibial grafts following laminectomy in the treatment of spondylolisthesis.

In the circumduction fusion described by Bosworth [5] and used in extensive laminal defects and severe cases of tuberculosis of the posterior portion of the spine, the transverse processes and posterior articulations are used as graft sites above and below the area of disease.

I believe that this procedure for grafting the posterolateral spine will give a higher percentage of successful results than can be obtained by extension of dissection and grafting from the mid-line exposure. The fusion bed can be better prepared and there is less tendency for the grafts to become elevated from contact with the transverse processes and pedicles. Another important advantage of this approach is that it obviates making a mid-line incision. In the author's series two patients with tuberculosis of the posterior element had fusion during which no diseased tissue was encountered. In one case of spina bifida with meningocele, the neurosurgical consultant was opposed to making an incision over a posterior sacral mound. Successful stabilization was attained in this patient with bilateral grafts imbedded by the posterolateral approach in one procedure. A number of patients in the series who had indications for posterior exploration had grafts placed from the mid-line on one side; on the other side, the posterolateral approach was used. In each instance the posterolateral incision provided a more adequate exposure and at the same time allowed access to an ample supply of iliac bone.

Autogenous iliac bone was used in all patients, supplemented in six by bone-bank bone. In all but two, massive iliac grafts were used. A single large graft from the posterior iliac crest conforms well to the angle of the lumbosacral joint and the most satisfactory graft for fusion of either one or two joints.

Although no complications arose from the use of screws, they were omitted in the last eleven operations. The improvement in the technique of seating the grafts and suturing the overlying muscles to secure them obviated internal fixation in these procedures.

More bleeding is encountered in the posterolateral approach to the spine, due to extensive soft-tissue dissection. There are no large vessels in this region, however, and blood loss need not be excessive. Blood oozing from the site of removal of the grafts from the iliac crest, unless adequately controlled before closure of the wound, may lead to postoperative hematomata.

COMMENTS

In twenty-eight patients who had posterolateral spine fusion, results were significantly better in the seventeen with bilateral operations, thirteen of which were performed in one stage and four in two stages. There were no failures of fusion in the seven primary procedures five of which were performed on patients with spondylolisthesis. In patients with spondylolysis or spondylolisthesis with minimal displacement, a one-joint fusion may be adequate. There were two such patients in this series.

Although the results in this series indicate a use for posterolateral fusion as a primary procedure in spondylolisthesis, further experience with a larger number of patients is necessary before forming definite conclusions. In the difficult problems encountered—pseudarthrosis and defects of the posterior elements of the lower lumbar and lumbosacral spine—bilateral grafting with autogenous iliac bone will result in solid fusion in a high percentage of cases.

Despite physical deterioration, emotional disturbance, and sense of despair in many of the patients in this series, the response to successful stabilization of the spine was rewarding. Many of the previously severely disabled patients undertook gainful occupations following posterolateral fusion.

NOTE: Four of the cases in this series were from the Veterans Administration Hospital, Kingsbridge, Bronx, New York.

REFERENCES

1. ADKINS, E. W. O: Spondylolisthesis. J. Bone and Joint Surg., **37-B:** 48-62, Feb. 1955.
2. ALBEE, F. H.: Transplantation of a Portion of the Tibia into the Spine for Pott's Disease. A Preliminary Report. J. Am. Med. Assn., **57:** 885-886, 1911.
3. BOSWORTH, D. M.: Techniques of Spinal Fusion: Pseudarthrosis and Method of Repair. *In* Instructional Course Lectures, The American Academy of Orthopaedic Surgeons, 1948. Vol. 5, pp. 295-313. Ann Arbor, J. W. Edwards, 1948.
4. BOSWORTH, D. M., and LEVINE, JACK: Tuberculosis of the Spine. An Analysis of Cases Treated Surgically. J. Bone and Joint Surg., **31-A:** 267-274, Apr. 1949.
5. BOSWORTH, D. M.: Circumduction Fusion of the Spine. J. Bone and Joint Surg., **38-A:** 263-269, Apr. 1956.
6. CAMPBELL, W. C.: Operative Orthopedics. St. Louis, The C. V. Mosby Co., 1939.
7. CLEVELAND, MATHER; BOSWORTH, D. M.; and THOMPSON, F. R.: Pseudarthrosis in the Lumbosacral Spine. J. Bone and Joint Surg., **30-A:** 302-312, Apr. 1948.
8. CLOWARD, R. B.: Vertebral Body Fusion for Ruptured Lumbar Discs; Roentgenographic Study. Am. J. Surg., **90:** 969-976, 1955.
9. HIBBS, R. A.: An Operation for Progressive Spinal Deformities. A Preliminary Report of Three Cases from the Service of the Orthopaedic Hospital. New York Med. J., **93:** 1013-1016, 1911.
10. HIBBS, R. A.: A Report of Fifty-Nine Cases of Scoliosis Treated by the Fusion Operation. J. Bone and Joint Surg., **6:** 3-37, Jan. 1924.
11. WATKINS, M. B.: Posterolateral Fusion of the Lumbar and Lumbosacral Spine. J. Bone and Joint Surg., **35-A:** 1014-1018, Oct. 1953.
12. WILTBERGER, B. R.: The Dowel Intervertebral-Body Fusion as Used in Lumbar-Disc Surgery. *In* Proceedings. J. Bone and Joint Surg., **38-A:** 932-933, July 1956.

DISCUSSION

DR. MARCUS J. STEWART, MEMPHIS, TENNESSEE: In 1953, Dr. Watkins discussed his technique for posterolateral fusion and gave a preliminary report of ten patients. Today, we have end results of twenty-eight patients with a high percentage of good results. The operation has been given a thorough test since it has been done only on difficult cases. Each patient

had had from one to five previous attempts at fusion; each of these patients presented a formidable problem. Bosworth, Adkins, and others have reported various surgical techniques for securing spine fusion in cases of tuberculosis, pseudarthrosis, and similar complications.

Probably the most essential step in securing fusion of the spine is the preparation of the posterior articulations and laminae to form a good bed for receiving the grafts. Second in importance is the addition of a proper amount of good osteogenetic substance, and nothing is better than fresh autogenous cancellous bone. Dr. Watkins' report assures us that he has fulfilled these criteria, and his operative technique is obviously that of a master surgeon. In my opinion, there are no avenues for major complications in this exposure. For most of us the anticipation of attempting new exposures is invariably more hazardous than the actual accomplishment of the procedure.

Fusion of the anterior part of the cervical spine would, upon first consideration, pose a rather difficult problem. About a year ago, I was confronted with a patient on whom neurosurgeons had done a complete laminectomy from the first to the seventh cervical vertebra following fracture-dislocation of the fifth on sixth cervical vertebra. Extensive laminectomy rendered it nearly impossible to do an adequate posterior fusion. This led us to investigate the possibility of an anterior approach. After careful review of the anatomy and performing the exposure on several cadavera, we gained more confidence. I secured the assistance of Dr. Edwin Cocke, an excellent nose and throat surgeon.

We used the same skin incision as that commonly used for thyroidectomy. Then, by displacing the neurovascular bundle lateralward and the trachea and esophagus to the opposite side, it was surprising with what ease we approached the cervical spine. The middle thyroid artery was the only structure of any importance that was sacrificed. Palpation of the osteophytes on the anterior surface of the cervical spine and comparison with roentgenograms made it easy to identify the level we wanted. However, the position was confirmed by roentgenograms made during operation. We next removed the annulus fibrosis, and curetted out the entire intervertebral disc, breaking through the table of cortical bone on the inferior surface of the fifth cervical body and the superior surface of the sixth cervical body. The intervertebral space was packed with fresh cancellous bone. A wedge of cortical iliac bone was placed between the fifth and sixth cervical segments anteriorly, so that the flat smooth surface of this graft prevented the cancellous bone from extruding from its bed. The graft allowed an even surface over which we closed the cervical fascia. The patient tolerated the procedure well, had no postoperative difficulty, and within eight weeks had solid bone fusion.

A few weeks later, Dr. Cocke assisted Dr. Harold Boyd in performing a similar procedure on a fifteen-year-old boy in whom three segments of the cervical spine were bridged. A cortical iliac graft was wedged into the body of the third cervical vertebra and fastened to the body of the fifth by a stainless-steel screw. The patient had no postoperative difficulty. The early good result and especially the ease of exposure in these two patients was most encouraging.

Dr. Watkins' posterolateral bone-grafting procedure offers us a real opportunity to help patients who present multiple complications in attaining lumbar and lumbosacral fusion. I would like to compliment him not only for this operation and its technique, but also for the manner in which he has presented his study.

Dr. Walter A. L. Thompson, New York, N. Y.: My experience is the result of having performed this operation on fifteen patients. Of this group, thirteen have been followed for more than a year with stress roentgenograms. This is not a simple operation; due to the vascularity of the operative area, bleeding was a problem. The operation has been facilitated by using a long U-shaped incision which makes it easy to work on the opposite side if one side has had to be packed.

A cautering knife has simplified this operation since it controls profuse multiple small bleeders.

Another aid has been the use of spinal anaesthesia to lessen intra-abdominal pressure. Postoperative ileus may be an annoying complication. However, it is never a serious one. I no longer use massive grafts since they can slip. Instead, a mass of long flexible iliac slivers are used. Originally, I performed this operation as a last resort in patients who had had multiple operations. Now I use it more and more as a primary procedure. As a primary procedure, it appeals to me and for the following reasons: (1) fusion cannot injure and irritate the underlying nerve roots and dura mater; (2) if late neurological exploration should become necessary, it is simply done; and (3) I feel that a greater number of really solid fusions can be obtained.

If it is necessary to subject an occasional patient to spine fusion, with all the danger this operation entails, we should select the operation which will most likely succeed even if more extensive.

Léri's Pleonosteosis

A Study of a Family with a Review of the Literature *

BY JOHN G. RUKAVINA, M.D., HAROLD F. FALLS, M.D., JOHN F. HOLT, M.D., AND WALTER D. BLOCK, PH.D., ANN ARBOR, MICHIGAN

From the Departments of Dermatology and Syphilology, Ophthalmology, and Radiology, University of Michigan, Ann Arbor

André Léri, in a series of publications [9,10,11,12], was the first to describe an unusual congenital and hereditary syndrome involving chiefly the osseous system. He applied the term *pleonosteosis* (from the Greek *pleon* which means superabundant) to this entity and postulated that the osseous abnormalities were due to a precocious and excessive ossification of the bones of cartilaginous origin associated with enlargement of the epiphyses. The typical syndrome consists of the following features: (1) shortness of stature, (2) Mongoloid facies, (3) short, spade-like hands, (4) broad thumbs in valgus position, (5) genu recurvatum, (6) flexion contractures of the digits of the hands and feet, (7) cubitus valgus, and (8) limitation of motion of the articulations of the body. The individuals and families studied, however, have shown variations in expressivity of the trait, a common occurrence in the majority of the hereditary aberrations of the skeletal system. Certain cutaneous changes have also been recorded which are: hollow palms, accentuated skin creases between thick palmar pads, and thickening of the hands, forearms, and facies, resembling scleroderma. Ophthalmological findings in the syndrome include Mongoloid slanting of the palpebral fissures, moderate thickening and tenseness of the skin of the eyelids, and (questionably) strabismus.

This report concerns what is believed to be the first American family to exhibit this rare entity. The available literature has been reviewed in order to define the syndrome more precisely and to emphasize certain dermatological and ophthalmological aspects. Study of the serum proteins by experimental electrophoretic methods (free boundary electrophoresis) was carried out in the hope of developing a biochemical diagnostic technique for confirming the clinical diagnosis in the affected subjects, and of uncovering consistent characteristic electrophoretic changes in apparently normal members of the family who might be expected to have a preclinical form of the disease. No such changes in the electrophoretic pattern in normal members of the family were found.

KINDRED

The family, on which this report is based, resides in the south-central portion of the lower peninsula of Michigan and was first encountered on April 4, 1950, when one of the authors (H. F. F.) observed the anomalous skeletal changes exhibited by the mother of one of his patients with strabismus. A pedigree was drawn up and it constitutes kindred 1806 of the files of the Department of Human Genetics, University of Michigan Medical School. The generations are indicated by Roman numerals and the various members of each generation (in birth order) by Arabic numerals. The propositus, the previously mentioned mother, is thus III-2; she will subsequently be referred to by that symbol. The family consisted of twenty-one Caucasian members. All available members of the family were examined both clinically and roentgenographically. Various laboratory studies, including free electrophoretic examinations of the serum, were also carried out.

* This study was supported in part by United States Public Health Service funds.

FIG. 1

Hands of III-1. Note multiple nodules on the deformed fingers.

CASE REPORTS

I-1. This man was thought to be the first individual in the family who was afflicted because his relatives recalled that he had exhibited the pathognomic deformity of the hands and feet. His gait was shuffling; gradually progressing limitation of joint motion developed. His carriage and physiognomy were reported to have resembled those of the living affected individuals in the family.

II-1. This woman, fifty-eight years old, mother of the propositus, had marked deformities of various joints. Palmar fasciitis was present in both hands in addition to thickening of the fascia of the forearms. Broad thumbs and great toes were associated with flexed, short, stubby fingers and toes. Limitation of motion of varying degree was found in the neck, shoulders, hips, knees, and elbow joints. A notable decrease of the normal lumbar lordosis was evident, giving the patient a characteristically straight, soldier-like carriage. She walked with short steps and her gait was somewhat waddling in nature. Function of her hands was impaired. When using a spoon or similar instrument, she would hold them between the proximal phalanges of the second and third fingers, with the broad and distorted thumb giving additional support.

Roentgenograms of the skeleton exhibited numerous changes. These included minimal generalized osteoporosis, slight scoliosis, moderate hypertrophic spurring, and widening of the vertical diameters of the posterior neural arches of the cervical spine. In addition, incomplete segmentation of the neural arches of the second and third cervical vertebrae was observed and roentgenograms of the hands and feet showed relatively short and broad metatarsals, metacarpals, and phalanges. These changes were not pronounced.

Biochemical and laboratory findings were: serum calcium, 9.2 milligrams per 100 cubic centimeters; alkaline phosphatase, 2.4 King-Armstrong units; blood non-protein nitrogen, 40 milligrams per 100 cubic centimeters; total cholesterol, 132 milligrams per 100 cubic centimeters.

The Kahn test was negative.

Serum electrophoresis (free moving boundary): abnormal, low α_2 and α_1 globulin.

III-1. This forty-year-old man was admitted to the University Hospital for the purpose of carefully evaluating an affected individual from an experimental biochemical point of view. The chief complaints of this patient were inability to walk with the heels on the ground; arthritis of neck, hands, and wrists; inability to make a fist, to tie his necktie, or button his collar; numbness of the hands; and the presence of variegated kernels or nodules beneath the skin of the fingers of both hands.

Past history indicated that the patient had had jaundice with complete recovery at six years of age. In 1932, a bilateral Achilles-tendon lengthening operation had been performed. A nasal operation had been performed in 1931 for an alleged bone growth. A dislocation of the

FIG. 2

Roentgenogram of the cervical spine. The vertical height of the posterior neural arches is strikingly increased, resulting in the reversal of the normal lordotic curvature.

right elbow in 1929 had resulted in marked limitation of motion in this joint. A vasectomy was requested by the patient because of his concern with the hereditary nature of his disease.

Physical examination revealed his height to be six feet one inch (taller than usual for this syndrome), weight 167 pounds, and his blood pressure 120 systolic and 80 diastolic. Ophthalmological examination showed narrowed palpebral fissures and Mongoloid slanting of the palpebral fissures. Otherwise the eyes were normal. Cardiovascular, pulmonary, and abdominal examination failed to reveal any abnormalities. The skin over the forearms and backs of the hands was indurated and bound down, suggesting a sclerodermatoid process. Small nodules, apparently subcutaneous and relatively immobile, were found on all the fingers (Fig. 1). These were not tender and showed no evidence of ulceration or sinus formation. Both hands manifested a definite puckering of the palmar fascia. Flexion deformities of the distal interphalangeal joints as well as limitation of motion of the proximal phalangeal joints were noted, but the metacarpophalangeal joints were not remarkable. Although the patient was not able to make a complete fist, his hand grip was strong. The musculature and subcutaneous tissues of the forearm were firm to palpation, especially on the volar aspects. The wrists presented limitation of motion with approximately 20-degree dorsal and palmar flexion. In the right elbow, there was a bone abnormality, apparently due to the dislocation; extension of the arm was limited to approximately 130 degrees; the left elbow could be flexed to 40 degrees. Extension and pronation of the left elbow were normal but supination was only 25 degrees. The shoulders permitted abduction to 90 degrees, while external rotation was found to be approximately 70 per cent of normal. The clavicular head of the sternocleidomastoid muscle apparently was absent. The musculature of the cervical spine was extremely firm to palpation and appeared to bulge prominently in the mid-cervical region. The patient could not extend the neck beyond the vertical position, and in maximum flexion the chin only came to within two inches of the chest. Lateral bending and rotation of the neck were 25 degrees and 40 degrees to the right and left, respectively. While motion of the lumbar spine was normal, there was a definite flattening of the dorsal curve, especially when the patient was standing. In the thoracic spine extension was limited to 50 per cent, lateral motion to 75 per cent, and rotation to 25 per cent of the normal. Surgical scars due to the Achilles-tendon lengthening

were present bilaterally. The gastrocnemius muscles were small when compared to the patient's over-all muscular development. Slight limitation of motion of the toes and marked restriction of motion of subtalar joints were apparent.

Roentgenograms of the skeleton exhibited the following: enlargement of the thoracic vertebral bodies in their anteroposterior diameters and a striking increase in the vertical height of the cervical vertebrae posteriorly which was associated with a reversal of the normal cervical lordosis (Fig. 2). The hands showed unusually short and broad metacarpals and phalanges (Fig. 3); the phalanges were more bulbous than the normal; the distal ends of the radii were somewhat overdeveloped. The changes in the bones of the feet were similar to those in the hands. Hallux valgus was present bilaterally. A peculiar wavy periosteal new-bone formation was present along the metatarsal shafts suggesting tuberous sclerosis to the roentgenologist. The skull exhibited several abnormal features; the occipital bone appeared to be small with greatly exaggerated ridges which involved only the external table; the sella turcica appeared to be displaced posteriorly in the skull, possibly a consequence of the decreased size of the occiput; the sella itself was small and difficult to outline because of the relative increase in

FIG. 3

Roentgenogram of the hand. Note the unusually short and broad metacarpals and phalanges.

size of the anterior and posterior clinoid processes; and all of the paranasal sinuses, with the exception of the sphenoid, were voluminous (Fig. 4). The clavicles were enlarged and the right eleventh rib was massive. A lumbar scoliosis, convexity on the left with the apex of the curve at the third and fourth lumbar vertebrae, was noted.

Microscopic examination of the dorsal skin from the left hand revealed marked fibrosis of the corium, with widespread hyalinization (Fig. 5). A minimal perivascular inflammatory infiltrate was visualized. The dense connective tissue appeared to be constricting some of the sweat gland elements. The findings appeared to be consistent with those of an early form of scleroderma. Microscopic study of a subcutaneous nodule from the right index finger revealed evidence of a foreign-body reaction (iron stain was positive).

Biochemical and laboratory findings were as follows: serum calcium, 10.4 milligrams per 100 cubic centimeters; alkaline phosphatase, 2.7 King-Armstrong units; blood non-protein nitrogen, 32 milligrams per 100 cubic centimeters; total cholesterol, 183 milligrams per 100 cubic centimeters (75 per cent esters); fasting blood sugar, 74 milligrams per 100 cubic centimeters; serum inorganic phosphorus, 3.4 milligrams per 100 cubic centimeters; serum bili-

rubin, 0.9 milligram per 100 cubic centimeters (one minute direct = 0.1 milligram per 100 cubic centimeters); cephalin flocculation, 0 (twenty-four hours) to +++ (forty-eight hours); gamma globulin, 130 units; thymol turbidity, 2-3 units; hemoglobin, 15.6 grams; white blood cell count, 5,200 with 52 per cent polymorphonuclear neutrophils, 9 per cent monocytes, 23 per cent lymphocytes, 5 per cent eosinophils, and 10 per cent basophils; platelet count, normal; basal metabolic rate, —8; serum electrophoresis, normal (free moving boundary). Electrocardiogram was normal as were roentgenograms of the gastro-intestinal tract.

III-2. The propositus was born in August 1916. She had first become acutely aware of her joint deformities when she was in high school. In retrospect, however, she recalled that she had been handicapped for many years, particularly in comparing her activities with those of her schoolmates. The patient was intelligent and was capable of excellent detailed paintings despite her joint immobilities. The fingers of both hands were markedly deformed with flexion deformities, thickening and shortening of the phalanges, enlargement of the interphalangeal joints and marked limitation of motility. The thumbs were broad, thick, and short. The feet were broad, short, and exhibited pes cavus. There were flexion deformities of all the toes with

FIG. 4

Roentgenogram of the skull. The paranasal sinuses are voluminous in character.

limitation of motion. The range of motion of the elbows, knees, hips, and shoulders was also decreased, while in the neck rotation and flexion were conspicuously limited.

Roentgenograms of the skeleton showed the following abnormalities. In the hands there was massive thickening of the metacarpals and phalanges. The trabecular pattern of the latter was prominent. The metatarsals and phalanges of both feet were also massive, particularly the metatarsal heads which were large, with a prominent trabecular pattern. The cervical and thoracic spine also showed the accentuated trabecular pattern seen in the bones of the extremities. The vertebral bodies and spinous processes were enlarged, as if due to appositional new-bone growth, particularly in the thoracic and cervical regions. These changes produced an increase in the anteroposterior diameter of the thoracic vertebral bodies. The sella turcica was normal in appearance. The changes observed in the spine and extremities were similar to those seen in acromegaly.

The Kahn test was negative; serum electrophoresis (free moving boundary) was normal except for a low α_2 globulin.

III-3. This pleasant, tall, well proportioned man of twenty-seven years had many of the distinguishing features of the syndrome which had been present since birth but had gradually increased in severity over the years. There was a conspicuous right convergent strabismus of at least 20 degrees (Priestly-Smith) but the extra-ocular movements were normal and the ocular ductions concomitant. The palpebral fissures presented a mild Mongoloid slant and blepharophimosis. The skin of the face and eyelids was tense and firm. The hands and feet were short, square, and broad. The thumbs and great toes were enlarged and incurved. There were flexion deformities of the toes and fingers, the latter being more affected. The motions of the neck, shoulders, hips, elbows, and knees were limited. The skin of the face and extremities was tense and thickened.

Roentgenograms of the skeleton revealed various abnormalities. There was an incomplete segmentation of the second and third cervical vertebrae, particularly in the region of the neural arches, and an increase in the vertical height of the posterior neural arches of all the

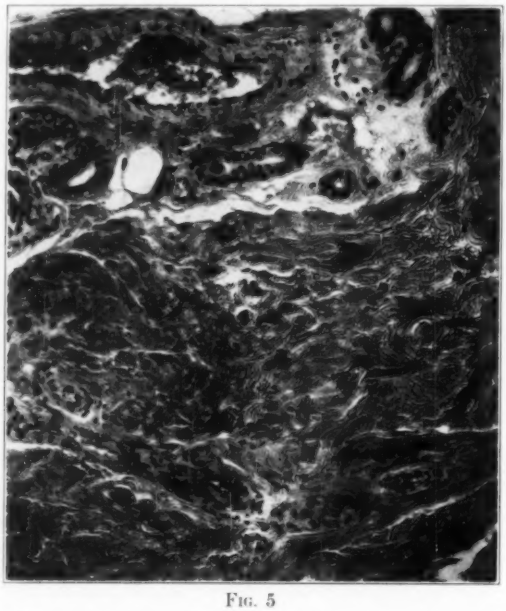


FIG. 5

Biopsy specimen of the skin (hematoxylin and eosin, high power) demonstrating hyaline changes, fibrosis, and dense islands of connective tissue in the dermis.

cervical vertebrae. In the hands and feet, there was shortening and broadening of the metacarpals, metatarsals, and phalanges, resembling that observed in the other affected members of the family. Minimal bilateral hallux valgus and slight calcaneal spurring were also noted.

Biochemical and laboratory findings were as follows: serum calcium, 9.4 milligrams per 100 cubic centimeters; alkaline phosphatase, 7.8 King-Armstrong units; total cholesterol, 91 milligrams per 100 cubic centimeters; blood non-protein nitrogen, 53.0 milligrams per 100 cubic centimeters.

The Kahn test was negative, and serum electrophoresis (free moving boundary) was normal.

IV-1. This boy was born in February 1941 with pes varus on the right which had responded satisfactorily to conservative treatment but still necessitated the wearing of corrective shoes. When last examined pes cavus was present bilaterally. An alternating convergent strabismus had been treated surgically with only moderate cosmetic improvement. No signs suggestive of Léri's pleonosteosis could be demonstrated by physical examination, roentgenographic studies, or serological tests. The patient was considered normal for the trait although he may represent a *forme fruste* in light of the changes in the lower extremities.

The Kahn test was negative, and serum electrophoresis (free moving boundary) was normal.

IV-2. This eight-year-old boy had been recognized by his mother as being affected at birth. The similarity of his short fingers and toes to her own had been only too apparent. At the time of examination the child was short for his age. His gait, like that of his mother, was shuffling, and the length of the stride was short. The mobility of the neck, shoulders, elbows, hips, and knees was limited and the hands could not be raised above the head. The skin of the face and the extremities was thick and tense. The facies exhibited a slight Mongoloid slant to the palpebral fissures, which were narrower than normal.

Roentgenograms of the skeleton showed changes similar to those in the other affected members of the family. There were, however, no changes in the cervical spine despite the clinical lack of motion. The bones of the hands were relatively short and broad and the general configuration of the bones of the extremities was characteristic of this condition.

The Kahn test was negative, and serum electrophoresis (free moving boundary) was normal except for an abnormal split α_2 globulin fraction.

FIG. 6

Photograph of III-2 illustrating slight Mongoloid slanting of palpebral fissures.

REVIEW OF THE LITERATURE

Since Léri [9,10,11,12] first called attention to the syndrome which now bears his name, approximately twenty-eight cases [1,2,3,4,5,6,7,8,13,15,16,17,18,20] have appeared in the available literature. Not all cases reported, however, appear to justify their inclusion in the description of this syndrome. Most frequently misdiagnosed as Léri's pleonosteosis are: Pfaundler-Hurler syndrome (both recessive and sex-linked recessive varieties), Morquio's disease, and congenital syphilis. From the viewpoint of the roentgenologist, as indicated in the family reported here, certain isolated changes might even suggest acromegaly or tuberous sclerosis.

In the twenty-eight reported cases, the sex incidence is twelve female and sixteen male. The ages, at the time of diagnosis, ranged from twenty-one days to fifty-three years. Partial or incomplete expressions of this pleiotropic gene (bone deformities, digital changes, facial asymmetry, and limitations of joint motility) were described among siblings, immediate or distant progenitors of individuals exhibiting the complete syndrome [1,2,3,4,5,6,13,18,20]. A negative maternal or paternal

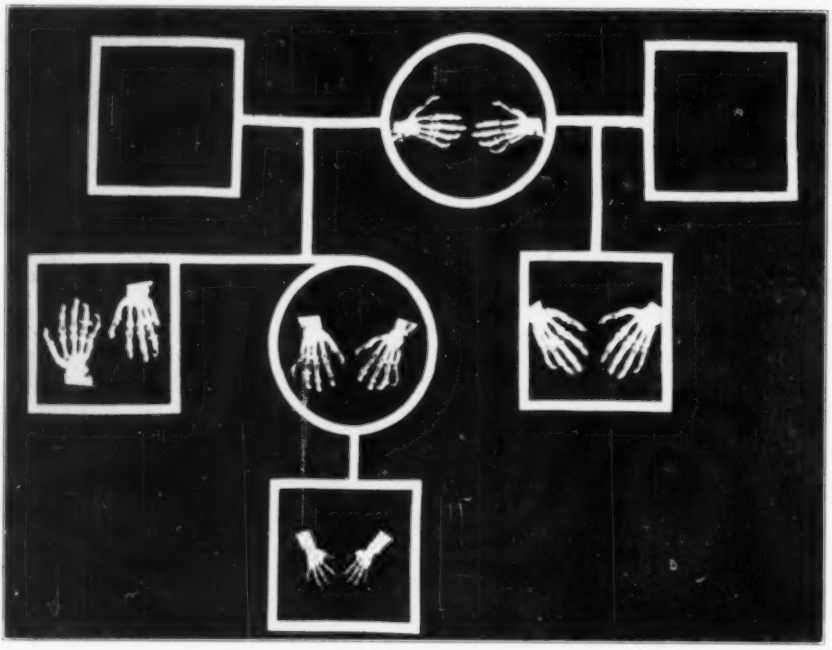


FIG. 7

Roentgenographic pedigree of skeletal hand changes.

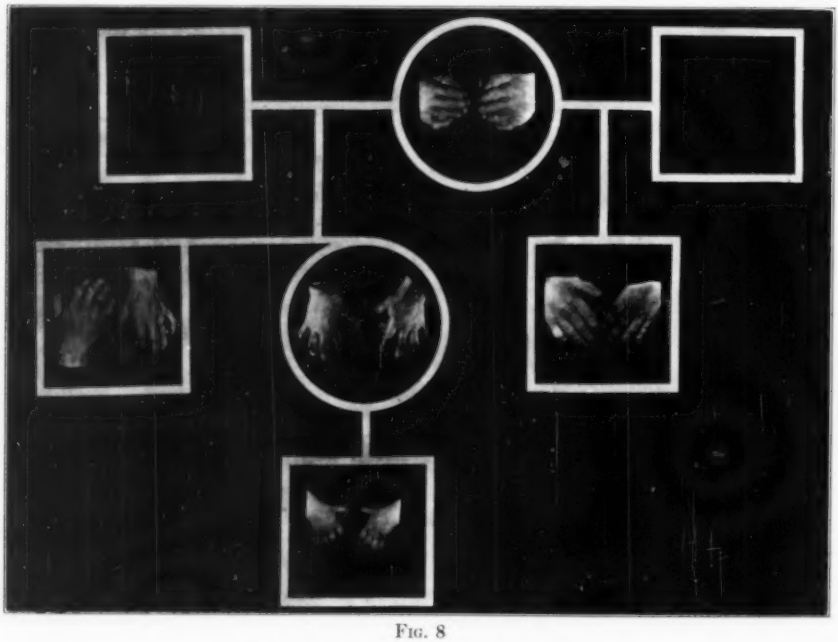


FIG. 8

Photographic pedigree of hand alterations.

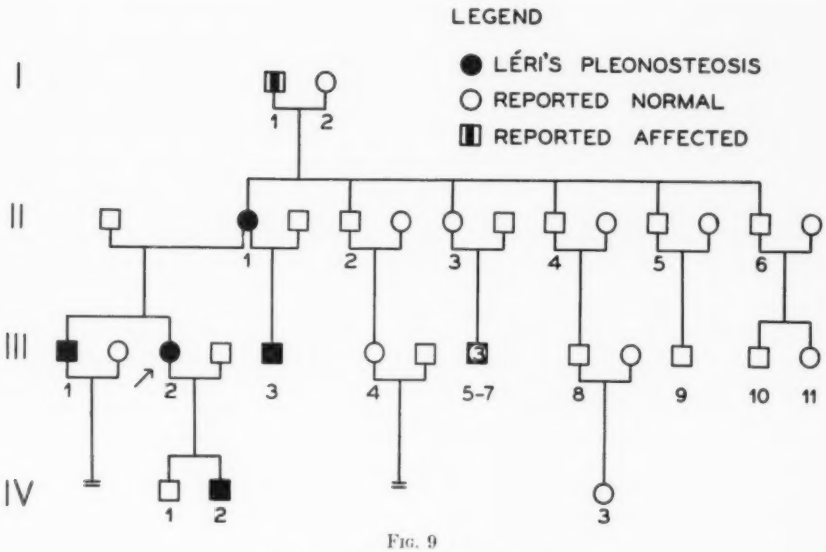


FIG. 9

Pedigree of kindred 1806 (see text).

history was noted in seven reports [5,6,8,15,16,17,20].

In Léri's family [10], the osseous abnormality was present in a father, a son by his first wife, and a daughter by a second wife (both spouses were apparently normal). The father was of short stature (sixty-two inches) with a thick neck and forward projecting head. He presented symmetrical anomalies of the upper extremities, flexed elbows, pronated forearms, and marked limitation of motion of the wrists. The hands were short and the fingers thickened. Flexion deformities of the proximal interphalangeal joints of the fingers were conspicuous. The thumbs were broad and deformed. Hollow palms and an accentuation of the skin creases between the thickened palmar pads were described. Genu recurvatum and thickened toes comprised the lower extremity changes. Limitation of joint motion was conspicuous and nearly universal. Early in life the children exhibited changes resembling, in miniature, those of their father.

Broad, deformed thumbs and great toes, flexion contractures of the fingers, thick stiff toes, limited joint motion, short stature, and Mongoloid facies thus characterized the original description of the disease. The probable accuracy of the diagnosis is somewhat clouded in the following cases:

1. That of LaRoche and Barthez: a four-year-old boy with a syphilitic mother. Many of the findings suggest congenital syphilis.

2. That of Apert: a six-year-old boy with skeletal changes suggestive of the sex-linked Pfaundler-Hurler syndrome.

3. Those of Hallé and Apert: three members of one family with mental deficiency, deafness, cachexia, and early death.

4. That of Feiguine and Tikhodéeff: a fourteen-year-old boy with dolichocephaly, arachnodactyly, and Mongoloid facies.

5. That of Rocher and Roudil: a male infant, twenty-six days old, with findings characteristic of Pfaundler-Hurler syndrome.

6. Those of Grebe: two brothers, nine and eleven years old, with features suggestive of Pfaundler-Hurler syndrome.

7. Those of Gareiso, Vijnovsky, and Pellerano: two brothers with features suggestive of Pfaundler-Hurler syndrome.

8. Those of Rocher: two siblings (a girl eight years old and a boy six years old) with findings suggestive of Pfaundler-Hurler syndrome.

9. Those of Materna: features in two brothers, aged thirty-nine and forty-two years, compatible with Pfaundler-Hurler syndrome.

The laboratory findings, mentioned in the literature, were meager or noncontributory. Incomplete electrolyte studies were within normal limits in one case [5] in which a profound leukopenia was described. A positive Bordet-Wassermann reaction was noted in the mother and the patient. The mother of the twenty-six-day infant also had a positive reaction for syphilis. Biopsy examination of skin or connective tissue was described in two cases [1,20]. The microscopic examination of a skin section in Apert's case demonstrated a normal cellular architecture but with a myxoedematous infiltrate. Watson-Jones summarized the histopathological changes found in the anterior carpal ligaments and in a plantar digital neuroma removed at surgery. In the former a marked increase in collagenous tissue was observed, a large proportion of which was actually fibrocartilage. A good deal of mucinous material was present, which was located in relation to cells and in linear deposits between collagen fibers. There was a conspicuous absence of elastic fibers. Atrophy and fibrosis of the muscle tissue attached to the biopsy specimen was seen. No vascular abnormalities were observed. The small nerves included in the section showed an early mucinous change and an increase of fibrous tissue in the endoneurium. In the plantar digital neuroma the constituent nerve bundles were separated by collagenous tissue which contained fibroblasts and small vessels. There was no conspicuous inflammatory infiltration, but tissue mast cells were scattered throughout the collagenous tissue. Several of the nerve bundles were swollen as a result of the presence of mucin. The pathological changes in the neuroma were concluded to be consistent with those seen in Volkmann's contracture.

COMMENT

Léri considered the pathological basis of pleonosteosis to be premature and excessive ossification associated with epiphyseal enlargement [11]. There is in general very little evidence to support Léri's concept of the pathogenesis. Watson-Jones, impressed with the striking changes in the carpal ligaments in his patient, postulated that the primary cause might be in the joint ligaments and that the bone thickening was secondary to periosteal traction at the metaphyseal attachments. Cocchi [19] considered the syndrome to represent a disturbance of the cartilaginous segments of the skeleton and classified it among the "polytopic endochondral dysostoses" (Morquio and Pfaundler-Hurler). It is apparent that much more information from biopsy and particularly necropsy studies must be accumulated before any clear-cut conclusion can be reached as to the pathogenesis of the syndrome.

The hereditary transmission of the gene responsible for Léri's pleonosteosis appears to be autosomal dominant, exhibiting fairly good penetrance and considerable variation in expressivity. Grebe and Weisswanger and Materna suggested a recessive mode of inheritance, but there is some doubt as to the validity of their conclusions. The accuracy of the diagnosis, particularly in Materna's case, is open to question on several counts. Cocchi [19] emphatically concluded that Léri's pleonosteosis is due to a dominant autosomal gene. Our incomplete survey of one family would support, at least superficially, the possibility of a dominant gene action.

The constant and essential features of Léri's pleonosteosis appear to be: broadening and deformity of the thumbs and great toes, flexion contractures of interphalangeal joints, limitation of motion of single or multiple joints, including the spine, short stature (considerable variance—Cases III-1 and III-3), and Mongoloid facies (great variance). Confusion seemingly has existed in differentiating between Léri's pleonosteosis and Morquio's disease or Pfaundler-Hurler syndrome (recessive autosomal with corneal opacity and sex-linked recessive form without

corneal opalescence) or congenital syphilis. Léri's pleonosteosis varies considerably in expressivity, as is true of most gene determined syndromes between affected individuals and between particular families. Since the gene responsible for Léri's disease exerts its action in a different gene milieu in each affected person, one would expect such variability as does exist. In fact, rarely will the physician find all of the so-called characteristic features present in one affected individual, it being necessary usually to study the entire family to ascertain the true range of the symptom complex. The characteristic Monogoloid facies, for example, is by no means a constant feature of the syndrome and even when present varies greatly in degree between the affected members of the same family. The ophthalmological findings of narrowed slitlike palpebral fissures, occasionally exhibiting an associated Mongoloid slanting, present in our patients and in others mentioned in the literature, may very well represent another of the pleiotropic features of the syndrome. Strabismus apparently occurs in a heightened incidence in individuals exhibiting the disease but further study is necessary before one can accept strabismus as a true feature of the syndrome. Opalescent or cloudy cornea and umbilical herniae are most certainly features characteristic of the Pfaundler-Hurler syndrome. Certain dermatological changes, heretofore not seriously considered as a part of the Léri syndrome, appear to be significant; these include separation of the palmar creases, thickened skin, scleroderma-like changes, and possibly disturbances of body hair. Osseous and musculoskeletal changes such as short hands, voluminous musculature, short limbs, rotational and contractural abnormalities of the extremities associated with joint enlargement may also properly complete this aspect of the syndrome. Roentgenographic findings, meager descriptions of which are found in only a few of the standard reference texts, may suggest the diagnosis of pleonosteosis but certainly are not specifically diagnostic. Overgrowth of the cartilaginous skeleton is manifested in an increase in the width rather than the length of the individual bones. This feature is accentuated by the shortness of stature, occasionally encountered in these patients, giving the skeletal parts an appearance of massiveness and great strength. As in acromegaly, the bones of the hands, feet, and vertebral column reflect the osseous overgrowth particularly well; it is this distribution of pleonosteosis rather than the appearance of individual extremities and vertebrae which may give rise to confusion in the differential diagnosis. In the family represented in this report, the most striking osseous abnormality is the bizarre enlargement of the posterior neural arches of the cervical vertebrae. Whether this proves to be of diagnostic significance depends on the consistency with which it is found in the study of additional families with pleonosteosis. It unquestionably represents overgrowth of bone and, in our experience, is a unique roentgenographic sign. Scalloped periosteal thickening of the metatarsus, a rather consistent finding in tuberous sclerosis, was observed in one patient. It is also observed occasionally in healthy individuals and is, therefore, thought to be of no diagnostic significance. Although the Pfaundler-Hurler syndrome has been cited as an important consideration in the differential diagnosis of pleonosteosis, it is our opinion that the roentgenographic signs of gargolyism are so clear-cut that difficulty would arise only in the extremely atypical case.

McKusick included Léri's pleonosteosis among generalized and hereditary disorders of the connective-tissue system. The microscopic findings in Watson-Jones' case support this hypothesis. The findings presented by the affected members in the family reported in this article further stress the generalized and systemic character of Léri's syndrome.

SUMMARY

A study of a family in which features of a systemic disease were exhibited consistent with the diagnosis of Léri's pleonosteosis has been presented. It is believed to be the first North American family to be reported. The findings are those of a widespread constitutional disease which involves chiefly the connective-

tissue system. The syndrome appears to be the consequence of a gene exhibiting an autosomal dominant mode of transmission. The gene presents good penetrance and a considerable variance in its range of expressivity. Certain ophthalmological, cutaneous, osseous, and roentgenographic findings present in the reported family and mentioned in the literature are considered as possibly being additional expressions of this pleiotropic syndrome. More necropsy material is needed with which to understand this important syndrome better.

REFERENCES

1. Apert, E.: Maladie familiale caractérisée par des épaississements osseu rappelant la pléonostéose, par une surdité progressive, et par une déchéance intellectuelle et physique condiusant à une issue fatale. Bull. Soc. Pédiat. Paris, **29:** 498-500, 1931.
2. Caussade, G., and Peynet, J.: Un Cas de pléonostéose familiale. Bull. et Mém. Soc. Méd. Hôp. Paris, **48:** 210-216, 1924.
3. Cohen, and DeHerdt: Pléonostéose familiale. J. Neurol. et Psychiat., **28:** 395-398, 1928.
4. Feiguine, E., and Tikhodéeff, S.: Un cas rare d'ostéopathie systématisée, un cas de pléonostéose (?) en U. R. S. S. Arch. Méd. Enf., **35:** 654-663, 1932.
5. Gareiso, A.; Vijnovsky, B.; and Pellerano, J. C.: Pléonostéosis familiar de Léri. Rev. Asoc. Méd. Argentina, **60:** 323-329, 1946.
6. Grebe, H., and Weisswanger, W. M. H.: Die chondrodysplasie und Verwandte Suplemerkrankungen im Roentgenbild. Fortschr. Geb. Röntgenstrahlen, **67:** 277-289, 1943.
7. Hallé, J., and Apert, E.: Pléonostéose familiale d'André Léri. Bull. Soc. Pédiat. Paris, **29:** 492-498, 1931.
8. LaRoche, G., and Barthes, A.: Un cas de pléonostéose chez un hérédo-syphilitique. Bull. Mém. Soc. Med. Hôp. Paris, **51:** 459-464, 1927.
9. Léri, A.: Une maladie congénitale et héréditaire de l'ossification: la pléonostéose familiale. Bull. et Mém. Soc. Méd. Hôp. Paris, **45:** 1228-1230, 1921.
10. Léri, A.: Dystrophie osseuse generalisée congénitale et héréditaire: la pléonostéose familiale. Press. Méd., **30:** 13-16, 1922.
11. Léri, A.: Sur la pléonostéose familiale. Bull. et Mém. Soc. Méd. Hôp. Paris, **48:** 216-220, 1924.
12. Léri, André: Études sur les affections des os et des articulations. Colonne vertébrale exceptée, pp. 5-34, Paris, Masson et Cie., 1926.
13. Materna, A.: Zur Pathologie der Pleonosteosis. Beitr. Path. Anat., **112:** 112-136, 1952.
14. McKusick, V. A.: Hereditary Disorders of Connective Tissue VIII, Concluding Comments. J. Chr. Dis., **3:** 521-556, 1956.
15. Rocher, H. L.: La pléonostéose (maladie de Léri). Rev. d'Orthop., **33:** 24-34, 1947.
16. Rocher, H. L., and Pesme, P.: Un cas de pléonostéose (maladie de Léri) avec cornées opalescents. J. Méd., Bordeaux, **123:** 121-125, 1946.
17. Rocher, H. L., and Roudil, G.: La pléonostéose (maladie de Léri). Etude anatomo-clinique et radiographique. Bordeaux Chir., **3:** 359-384, 1932.
18. Rouillard, J., and Barreau, P.: Un nouveau cas de pléonostéose héréditaire avec atteintes graves des grosses articulations. Bull. et Mém. Soc. Méd. Hôp. Paris, **51:** 794-802, 1927.
19. Schinz, H. R.; Baensch, W. E.; Friedl, E.; and Uehlinger, E.: Roentgen Diagnostics. Ed. 5. Vol I, part I, pp. 727-728. New York, Grune and Stratton, 1951.
20. Watson-Jones, Reginald: Léri's Pleonosteosis, Carpal Tunnel Compression of the Median Nerves and Morton's Metatarsalgia. J. Bone and Joint Surg., **31-B:** 560-571, Nov. 1949.

Bone-Graft Operations to Lengthen the Humerus in Short Arm Amputation Stumps

Report of the Results in Two Bilateral Above-the-Elbow Amputees *

BY MARSHALL R. URIST, M.D., AND ROBERT MAZET, JR., M.D.,
LOS ANGELES, CALIFORNIA

From the Division of Orthopaedics, Department of Surgery, University of California, and Wadsworth Hospital, United States Veterans Administration Center, Los Angeles

Bone-grafting to extend the length of the humerus in an amputation stump has been often contemplated, seldom indicated or attempted, and rarely if ever before described in the literature. This type of surgical operation and the process of repair will be described in two patients with bilateral amputation of the upper extremities. One had a right shoulder disarticulation and the other had a right arm stump that did not tolerate a prosthesis for more than an hour without considerable discomfort. Their left stumps were too short for any appreciable function. The object of surgical treatment was to produce useful left arm stumps.

Case 1. A young woman, twenty-four years of age, a graduate dentist, had both arms burned off just below the shoulder by high-voltage electricity. The tragedy occurred when she was pushing a small sailboat through the shallow water in a marina. The mast struck a live wire and brought it down across her outstretched arms. Two short, unsatisfactory stumps were all that remained of her upper extremities. She was completely dependent upon her husband for care and feeding. Over a period of ten years, she became the mother of two children. To try to increase her usefulness to her family, she registered in the Upper Extremity Prosthesis Case Study Group at the University of California in Los Angeles. She was fitted with an artificial limb for the right arm. She was intelligent and dextrous, and she mastered the use of this prosthesis better than most. An attempt was made to fit the left arm also; this failed because the stump was too short to produce any useful function.

Physical Examination

The patient was an unusually intelligent, normally developed woman who was well adjusted to her handicap. The only abnormality was in the loss of her arms.

Right arm stump: The right arm was amputated at a level twelve centimeters distal to the glenohumeral joint line. The stump was atrophied, and there was a large sagging mass of fatty, soft tissue and skin hanging from the distal end. The skin on the inner side of the mass was inflamed and oedematous due to friction and pressure from the socket of her prosthesis. The scar was stellate in shape and contracted over the very center of the bone end. Between the end of the bone and the scar, the soft parts were tender and contained what was presumed to be a neuroma of the median nerve. There was also a deeper area of tenderness and an immovable mass of hard tissue at the medial margin of the bone end.

Left arm stump: The left arm had been amputated approximately six centimeters from the glenohumeral joint line, at the level of the surgical neck of the humerus. The superior and posterior portions of the greater tuberosity, including the tendinous attachments of the supraspinatus, infraspinatus, and teres minor muscles, were intact and functional. The patient was able to revolve the head of the humerus freely on all sides inside the glenoid fossa. The soft parts, comprising the outer envelope of larger muscles of the shoulder, appeared to be atrophied, nonfunctional, and consisted chiefly of the proximal portion of the belly of the deltoid. A mass of skin, fat, areolar tissue, fibrous tissue, and scar hung down, two to three inches below the end of the bone. These tissues appeared to be stretched by the effects of gravity; they were an obstacle to the fitting of a socket for an artificial limb. The scar

* These investigations were aided in part by grants from the Josiah Macy, Jr. Foundation, the Averst Laboratories, Inc., the Lee S. Mytinger Foundation, and the Easter Seal Foundation for Crippled Children and Adults.

FIG. 1-A

FIG. 1-B

Fig. 1-A: Case 1. Roentgenogram showing amputation stump with the bone line across the surgical neck of the humerus.

Fig. 1-B: Roentgenogram made following bone-graft operation in which an autogenous graft consisting of the upper end of the fibula was implanted inside the humeral head and an envelope of the soft parts hanging from the shoulder.

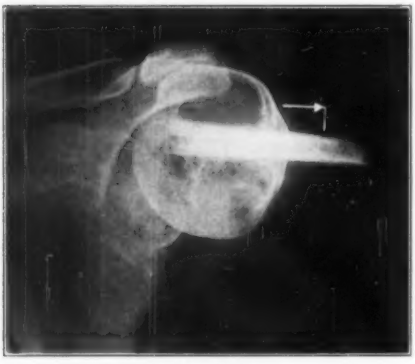


FIG. 1-C

Roentgenogram made following excision of the distal end of the graft. After two years, the area of increased radiodensity outside the humerus, indicated by the length of the arrow, may demarcate the segment of the graft undergoing replacement by new bone. Beyond this point, the substance of the donor tissue appears to be undergoing absorption.

was contracted over the end of the stump and extended upward across the anterior aspect of the axilla (Figs. 1-A through 1-G).

Laboratory studies: The blood cytology and chemistry and the urinalysis showed values within the limits of normal.

Preoperative roentgenographic examinations: The right arm stump of the humerus showed a small bone spur over the medial side of the bone end. The left arm stump showed normal bone structure and a transverse bone line across the area between greater and lesser tuberosities of the humerus.

TREATMENT

On September 10, 1954, the neuroma and bone spur were removed and the old scar was excised from the right stump. On September 18, 1954, a surgical procedure was devised to attempt to produce functional lengthening of the left humerus and thereby improve the capacity of the stump to activate an artificial arm.

The stump of the left arm was exposed after excision of the scar tissue on the anterior aspect of the axilla and shoulder. The deep extensions of the cicatrix were excised and the bone end was freed of all soft tissue by means of sharp dissection. This produced an open sac hanging from the shoulder joint with walls consisting of skin, subcutaneous fat, fibrous tissue, and atrophied muscle.

While the procedure was being completed, an assistant excised the proximal ten centimeters of the fibula. The articular cartilage and ligaments were excised from the head of the fibula with the use of osteotomes and a small ronguer. The bone was reshaped with a raspatory until it was nearly cylindrical at the distal end.

A channel was made in the center of the head of the left humerus with the aid of a three-eighths of an inch drill. The graft was inserted into the canal with the proximal end (head of the fibula) extending distalward and filling the bag

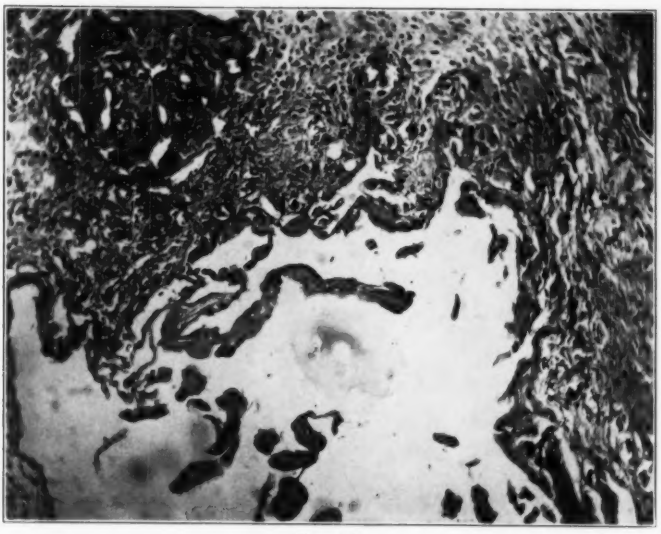


FIG. 1-D

Photomicrograph of the bursa excised from the soft parts over the end of the graft six to seven months after the original operation. The bursa was lined with fibrinoid material and filled with mucinous fluid.

of the soft parts suspended from the left shoulder. The wound was closed in layers with black silk sutures.

The patient was fitted with a left arm prosthesis two months after the operation but the stump became painful after a few minutes of use. Four months after the operation, an ulcer developed in an adherent area of skin on the end of the stump. A longer period of healing before application of a prosthesis might or might not have avoided this complication.

First Revision Operation and Biopsy Observations

Revision of the stumps was performed five months postoperatively to repair the skin and to remove enough of the graft to allow the soft parts to move more freely over the bone end. The healed scar and the ulcerated area of the skin were excised by means of a fishmouth incision over the end of the stump. One centimeter of bone was removed from the end of the graft along with a bursa filled with mucinous fluid. Microscopically, the lining of the bursa consisted of mesothelium and fibrinoid similar to that observed in the center of the callus of an unlimited fracture [2]. There was granulation tissue inside the old marrow cavity of the graft; this bled as profusely as the surrounding soft parts.

Removal of the bone and soft parts reduced the graft from ten to nine centimeters and recessed the bone line from a subcutaneous position to a place proximal to the deep fascia of the upper arm. The wound was closed loosely in a single layer with black silk suture. The stump drained seropurulent material and healed slowly. After six weeks, the patient again began to use an artificial limb, but the stump was red, swollen, tender, and still quite painful.

Second Revision

Seven months after the operation, a second revision of the stump was necessary in order to relieve pain and to excise more necrotic bone. The healed scar was excised, and the end of the stump was found to be covered with a mass of inflammatory connective tissue. The obviously necrotic tissues were excised and the length of the graft was reduced from nine to approximately eight centimeters.

FIG. 1-E

Artist's drawing showing the topographical relationship between bone and soft parts around the end of the stump, as well as the position of an autogenous graft of the fibula after excision of the head of the fibula.

This recessed the bone line of the stump to a position beneath the muscle line, especially beneath the remnant of the belly of the deltoid. The wound was closed loosely in a single layer with black silk suture. The stump drained serosanguinous fluid for ten days and eventually healed and became perfectly padded with soft parts, that were freely movable and non-painful, over the end of the graft. The length of the graft protruding from the neck of the humerus was estimated to be five centimeters and the length inside the neck, three centimeters.

Microscopic observations: The fragment of bone that was removed from the end of the graft after the second revision, six months after the original operation, contained both viable and non-viable connective-tissue cells, but for the most part

FIG. 1-F

FIG. 1-G

Fig. 1-F: Photograph of the patient showing the reconstructed stump eighteen months after the original operation and after it was used to activate a prosthesis.
Fig. 1-G: Photograph showing the type of prosthesis prescribed for this woman.

the osseous tissue contained pyknotic osteocytes or empty lacunae. The bone tissue appeared to be undergoing resorption inside an envelope of fibrous tissue containing many foreign-body giant cells. There were no large cells residing in lacunae that could be recognized as osteoclasts.

Postoperative roentgenographic examination: One year after the second revision, and approximately eighteen months after the initial procedure, the distal end of the bone graft appeared smooth on the lateral edge and sharpened on the medial edge. There was no outgrowth of new bone on the periosteal side at the point of attachment to the head of the humerus.

End-Result

The patient was not permitted to wear a prosthesis for her left arm until six months after the last revision, and she was urged to use it cautiously for an additional three months. On April 25, 1956, approximately one and one-half years after the graft was implanted, she demonstrated painless function of an arm stump that had previously been useless. On May 1, 1958, three and one-half years postoperatively, she was still learning ways to increase the use of the reconstructed left stump. Her right stump was, of course, more efficient and she wore her left prosthesis only when she was not wearing the right prosthesis. The harnessing of the shoulder girdles for the prostheses restricted the patient so she could not use the full length of the cable and hence, she could not use both arms at the same time. She felt that the bone graft improved the left arm stump to the extent that she could rely on it whenever the skin of the right arm stump was irritated from overuse. The patient was able to feed herself with a "spork", use many different kinds of household appliances, drive an automobile, clean house, and cook for her family.

CASE 2. A retired railroad switchman, sixty-five years of age, lost both arms when he was run over by a box car in 1941. He was afflicted with chronic alcoholism before and after

FIG. 2-A

Case 2. Photograph of a man (Case II), sixty-five years of age, showing a right shoulder disarticulation and a left arm articulation stump lengthened with the bone graft shown in Figs. 2-B and 2-C.

FIG. 2-B

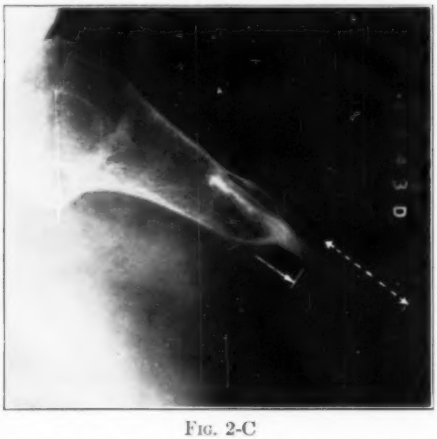


FIG. 2-C

Fig. 2-B: Anteroposterior roentgenogram of the stump. The bone spur formed on the lateral aspect of the stump under the attachment of the deltoid muscle.

Fig. 2-C. Roentgenogram of the stump showing interwoven pattern of the cancellous bone of the host and the lamellar bone of the donor. The high radiodensity of the segment of the graft inside the humerus, and only a short segment of the graft outside the humerus, indicated by the length of the arrow, may indicate the segment of the donor bone that was replaced by new bone that grew out from the humerus of the host. The low radiodensity of the distal end of the graft, indicated by the double-headed broken arrow suggests that the donor tissue has been resorbed in this area.

this accident. The information available about the patient is limited; he could not recall the name of the hospital in which he received treatment. A survey of the orthopaedic surgeons in the city produced no one who could identify his case history. The right shoulder was disarticulated and the left humerus was amputated approximately six inches from the glenohumeral joint line. In 1944, an autogenous graft from the crest of the tibia, approximately twelve centimeters in length, was transplanted into the medulla of the end of the shaft of the left humerus. The full length of the graft was enclosed in a sac of atrophied skin and subcutaneous areolar tissue, that hung from the stump, distal to the attachment of the deltoid. The bone was slightly tender to palpation and apparently uncomfortable when enclosed in a prosthesis. A hard nodule was palpable beneath the attachment of the deltoid, but this was not so troublesome as the pain on the end of the bone graft. The patient made repeated attempts to use various new and improved models of artificial limbs; the performance was erratic and he complained that pain, redness, swelling, or discoloration of the

skin prevented him from wearing any kind of prosthesis on the left stump for more than one hour (Figs. 2-A, 2-B, and 2-C).

Roentgenographic examination: The bone graft showed maximum radiodensity over a distance of two centimeters inside the end of the humerus and one centimeter outside the humerus. Distal to this point, the graft was less dense than normal bone, possibly due to disuse atrophy or resorption. There was a spur of new bone on the lateral aspect of the stump of the humerus, presumably unrelated to the substance of the bone graft.

End result: The patient's inadequate personality made it difficult to rehabilitate him and in retrospect he was a poor candidate for this reconstructive surgical operation. The result observed fourteen years after the procedure was graded good from the anatomical standpoint, poor from the economic standpoint (although the patient sporadically did carry trays in a bar room for brief periods with the aid of his artificial limb), and poor from the functional standpoint because he refused to wear a left arm prosthesis and had phantom pain in the stump.

DISCUSSION

According to Kessler, the procedure described in this communication has been attempted in the past in a number of unreported cases but found unsatisfactory so that revision operations were necessary [1]. The reasons for such experience must be examined in detail and recorded.

A bone transplant was no substitute for viable bone and could not assume the mechanical function of hard tissue in an amputation stump except temporarily and to a limited extent. A fresh autogenous-bone graft with one end embedded in osseous tissue and one end surrounded by soft parts showed two different responses of the host. One response was seen as increased radiodensity of the graft enclosed in the stump of the humerus. Another response was seen as decreased radiodensity in the portion of the graft extending out into the soft parts. In Case 1, the host bone was so close to the joint line that it had no periosteal covering, but in Case 2, there was periosteum and an osteogenetic reaction was produced on the periosteal surface of the host bone. The portion of the graft extending into soft parts showed no spurs or new-bone formation on the external surfaces. In Case 1, however, there was a spot of amorphous calcification on the tip of the medial edge of the graft presumably inside the bursa that formed over the bone end. The soft parts showed three successive reactions in the three parts of the stump.

Skin line: The end of the graft was allowed to protrude into the subcutaneous space in the initial procedure in the cases described in this report. This proved to be incompatible with function and produced pain, swelling, oedema, and inflammation in both cases, and was followed by ulceration and infection of the wound in Case 2. While this position of the bone end may be permissible in stumps with viable host-bone tissue, it was not tolerated around a relatively non-viable bone graft.

Fascial line: After the first revision operation of Case 1, the end of the bone graft was encapsulated in the soft parts or deep fascia. This was no better tolerated than the subcutaneous position, because it did not provide enough soft-tissue covering. The patient used the prosthesis, but only until an acute bursitis developed in the space between the soft parts and the end of the graft.

Muscle line: After the second revision, when the length of the graft was reduced more than two centimeters (Case 1) and after the bone end was deeply buried beneath the remnant of the belly of the deltoid, the stump showed a more physiological form and function. The skin and soft parts moved freely over and around the bone graft, and if a bursa developed, the patient did not have bursitis, and was able to use the stump painlessly to operate a prosthesis part of the time.

The end result was poor in Case 2, probably because the bone graft was not embedded deeply in muscle on all sides. By palpation of the stump it was easy to

note that the bone protruded into the subcutaneous space or fascial space and presumably caused skin irritation. This stump also became too painful to tolerate any kind of an arm prosthesis. It was difficult in Case 1 to resist the desire to implant a length of graft that completely filled the sac of skin hanging from the end of the stump. This proved to be unphysiological and doomed to failure. The length of graft appears to be limited to that which can be buried in muscle on all sides.

Osteogenesis

In Case 1, the graft was tubular; in Case 2, the graft was solid cortical bone. Although autogenous material, there was no evidence to assume that either form of tissue survived transplantation. The alteration in the shape of the end of the tubular graft suggested that it was absorbed more rapidly than the solid graft. A large part of the transplant was not replaced by visible bone even after a long period of time. Apparently total replacement is most likely to occur only in transplants of bone surrounded on all sides by a host bed of living bone of a young growing individual.

The transplants had a free end extending into soft parts. Our observations on ununited fractures of the tibia suggested that replacement can occur in a bone end at a rate of 0.5 centimeter per year [2]. If the rate of bone replacement were the same in the bone grafts with one free end as in bone grafts in ununited fractures, the time required to reconstitute a five-centimeter fibular transplant in this case would be ten years! This was measured by serial roentgenographic examinations by assuming that the area of the graft with increased radiodensity was the area of appositional-bone formation and that the area of bone tissue with decreased bone density was the part of the graft undergoing a foreign body, non-osteoclastic type of resorption. However, this being purely a roentgenographic change, it gives no information about the viability of bone tissue of either the host or the donor. In Case 2, if this interpretation of the roentgenogram is correct, no replacement of the graft by the host new bone extended beyond approximately two centimeters after as long as fourteen years. It is not unlikely that the rate of osteogenesis subsidies after two years, and that in adult or non-growing individuals, 2.0 centimeters ($\pm$0.5 centimeter) is the limit that new-bone formation will extend along a bone graft placed in the end of an amputation stump.

CONCLUSIONS

1. Two patients with high above-the-elbow arm amputation stumps, too short for function, had large areas of soft tissue hanging below the bone ends. Massive autogenous-bone grafts were implanted to elongate the humerus, produce internal rigidity in the end of the stump, and increase the length of the lever arm that could activate a prosthesis.

2. When the graft extended into the subcutaneous space, under moving skin and soft parts, it caused persistent inflammation, fibrinoid degeneration, and painful bursitis. When the graft was shortened to a position deeply recessed in muscle, it was well tolerated and capable of a limited form of function in the use of an artificial limb.

3. The donor tissue was replaced by new bone from the host along a distance of only approximately one centimeter. Beyond this point, on the basis of its roentgenographic characteristics, the bone graft appeared to remain inert and either unreplaced or slowly resorbed.

4. This procedure is of limited value and can be recommended only for unusual stumps having a large muscle mass in which to bury the transplant.

REFERENCES

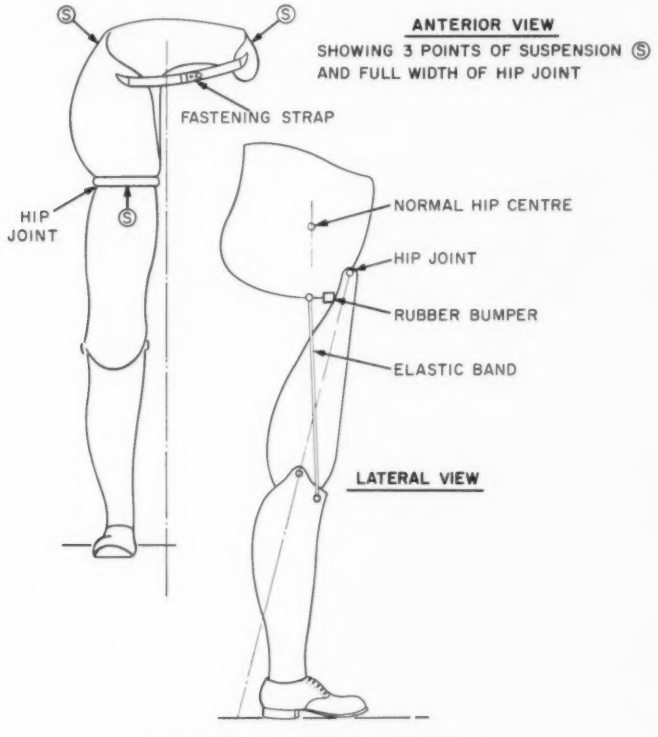
1. Kessler, H. H.: Personal communication.
2. Urist, M. R.; Mazet, Robert, Jr.; and McLean, F. C.: The Pathogenesis and Treatment of Delayed Union and Non-Union. J. Bone and Joint Surg., **36-A**: 931-967, Oct. 1954.

The Use of a Bilateral Canadian-Type Hip-Disarticulation Prosthesis for Congenital Absence of Both Lower Extremities

A Case Report

BY CLINE D. HENSLEY, JR., M.D., WICHITA, KANSAS

Rehabilitation of the amputee after hip disarticulation has long been delayed by inadequate prosthetic appliances. Until recent improvements, the prosthetist's armamentarium was limited to the tilting table or the saucer socket prosthesis. Both of these devices required the use of a pelvic belt and manually controlled hip lock. It was difficult or impossible to achieve an acceptable gait



FUNCTIONAL FEATURES OF CANADIAN HIP DISARTICULATION PROSTHESIS

Fig. 1

A line projected through the centers of the hip and knee joints passes posterior to the heel. Modified version of drawing appearing on page 4 of *The Canadian Type Hip Disarticulation Prosthesis* by James Foort and C. W. Radcliffe. Prosthetic Devices Research Project, Institute of Engineering Research, Series II, Issue 28. Berkeley, The University of California, 1956.

FIG. 2

Anteroposterior view of the pelvis.

FIG. 3

FIG. 4

Fig. 3: Five-year-old boy with congenital absence of both lower extremities shown without the prosthesis.

Fig. 4: View of the prosthesis with the patient sitting.

FIG. 5

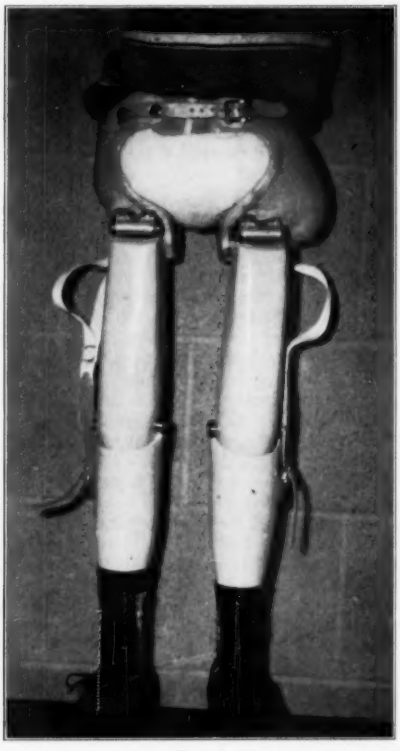


FIG. 6

Fig. 5: Lateral view of the patient standing wearing the prosthesis. There is forward placement of the hip and posterior placement of the knee.

Fig. 6: Front view of the prosthesis with the patient standing.

with either of these prostheses, and motions of sitting and standing were hampered because of the necessity to engage and release the hip lock.

These difficulties are, of course, increased in the case of the amputee with bilateral hip disarticulation. These factors prevented the successful application of a prosthesis to the patient reported here until the advent of the Canadian-type hip-disarticulation prosthesis.

The Canadian prosthesis was developed and reported by McLaurin in 1954. The Prosthetic Devices Research Project at the University of California in Berkeley popularized this prosthesis in the United States. Briefly, the prosthesis was designed to stabilize the hip and knee by alignment of the weight-bearing line posterior to the prosthetic hip joint and anterior to the knee axis with the patient standing (Fig. 1). Foort and Radcliffe gave a detailed account of the prosthesis; specific information concerning evolution, construction, and experience with the prosthesis is available [1,2,5,6]. Successful demonstrations at the University of California at Los Angeles prompted the use of the Canadian prosthesis in the patient reported.

K. R. S. was seen in the Amputee Clinic sponsored by the Kansas Crippled Children's Commission in December 1956. The child's age at that time was four years and nine months. He had congenital absence of both lower extremities and congenital absence of one finger of the right hand. He had excellent control of both upper extremities and good function of the right hand in spite of the relatively minor congenital deformity of the hand. Normal alignment and control of the trunk was present. A short, deformed atavistic femur was

present on the left with dislocation of the head out of the acetabulum to a position against the upper portion of the ilium (Fig. 2). On the contralateral side no femur was present.

The child had been fitted elsewhere with a pair of shortened prosthetic appliances designed to provide balance and some elevation of the trunk from the floor. In September 1956, these appliances had been lengthened and a foot and ankle assembly had been added. The mother stated that the result was unsatisfactory because the child was unable to maintain his balance, and discomfort resulted from contact between the projecting stub of the femur and the prosthesis on that side. The child was unable to stand or walk with the prostheses because of discomfort and subsequently they were discarded.

In January 1957, the construction of the bilateral Canadian-type hip-disarticulation prosthesis was undertaken by the prosthetist, Mr. F. L. Lake, in cooperation with the author. Fabrication and fitting of the socket was done according to the method described by Foort and Radcliffe. The length of the prosthetic limbs was determined by reference to height charts of normal children, and the ratio of the thigh to the leg was derived by measuring other children in the amputee program. The two sides of the socket were connected by a flexible leather hinge posteriorly and by a strap and buckle anteriorly. A check socket was used in the original fitting of the prosthesis. The final socket had an initial satisfactory fit and did not require alteration in nine months of follow-up study. The actual construction of the prosthesis was delayed some months while an effort was made to learn of any previous experiences with the Canadian-type hip-disarticulation prosthesis for bilateral amputees.

In September 1957, the prosthesis was delivered and training of the child in the use of the appliance began. Out-patient training was conducted in the Physical Therapy Department of St. Joseph Hospital, Wichita. Originally, the training periods were daily; within one month they were reduced to three times a week; and after two months they were discontinued. The child was taught to walk with Canadian crutches which could be easily disengaged in the event he fell. He was also instructed to use a walker.

In December 1957, the child went to school for the first time and was able to attend on a half-day basis for the remainder of the school year. At the time of writing, he wore the prosthesis for three-hour intervals for a total of six to eight hours during each day. He walked with a four-point gait with crutches or a walker. He accomplished this by lifting the trunk slightly with the hands and by a combination of flexion and internal rotation of the pelvis to initiate the swing phase of gait. His gait was cosmetically acceptable, but slow. The child could also walk well with a swing-through gait using the walker. He was able to walk approximately one-half block with crutches, but he exerted more effort than was necessary with the walker. He could walk approximately one block with the walker before requiring rest. He was unable to climb stairs or step off curbs, and did not play actively wearing the prosthesis.

Nine months after the delivery of the prosthetic appliance, the child was able to put the legs on after breakfast and wear them throughout the morning. He rested without the legs during lunch hour and during a period in the afternoon. The prosthesis was again fitted late in the afternoon and for the evening meal. The child's mother stated that he was becoming more proficient in the use of the prosthesis, and it is the opinion of the prosthetic team that no undesirable habits have appeared thus far in the relatively short follow-up period. The child has not complained of pain and has had no evidence of skin irritation at the point of contact between the prosthesis and the stump. No shoulder harness or other harness above the waist was required. He was able to sit in a balanced position and, without assistance, could sit down from a standing position. He was also able to stand up in the walker from a sitting position without assistance. The child was also able to stand alone and balance without supporting himself with crutches. In school, he has been able to stand up from a sitting position in a kindergarten chair by holding on to a table or other object.

The basic design of the prosthesis is that described by Foort and Radcliffe with modifications required because of the presence of bilateral deformity. Although the follow-up time has been short, the use of this device has, in my opinion, enabled this child to attain a degree of independence which has previously been impossible. It is expected that the present socket will require revision within the year because of growth of the child. The construction and fitting of the prosthesis did not entail as many difficulties as were anticipated. In gait-training, an effort was made to encourage the child in the use of a four-point gait with the walker.

NOTE: The author is indebted to Mr. F. L. Lake, C.P.O., of the Hanger Artificial Limb Company for the technical design and fabrication of the prosthesis used in this instance. Suggestions from Mr. John Bray, prosthetics instructor at the University of California at Los Angeles, were also utilized in the final design of the prosthesis. Training was supervised by Miss Naomi Wesson, Physical Therapy Department, St. Joseph Hospital, Wichita.

REFERENCES

1. Foort, James: Construction and Fitting of the Canadian-Type Hip-Disarticulation Prosthesis. Artif. Limbs, **4**: 39-51, 1957.
2. Foort, James: Some Experience with the Canadian-Type Hip-Disarticulation Prosthesis. Artif. Limbs, **4**: 52-70, 1957.
3. Foort, James, and Radcliffe, C. W.: The Canadian Type Hip Disarticulation Prosthesis. Prosthetic Devices Research Project, Institute of Engineering Research, Series II, Issue 28. Berkeley, University of California, 1956.
4. McLaurin, C. A.: Hip Disarticulation Prosthesis, Report No. 15. Toronto, Prosthetic Services Center, Sunnybrook Hospital, 1954.
5. McLaurin, C. A.: The Evolution of the Canadian-Type Hip-Disarticulation Prosthesis. Artif. Limbs, **4**: 22-28, 1957.
6. Radcliffe, C. W.: The Biomechanics of the Canadian-Type Hip-Disarticulation Prosthesis. Artif. Limbs, **4**: 29-38, 1957.

Femoral Torsion and Its Relation to Toeing-in and Toeing-out*

BY LAWRENCE CRANE, M.D., PORTLAND, MAINE

Toeing-in and toeing-out may be caused by changes at any level of the lower extremities. Conditions in the feet which cause these abnormalities are quite clearly understood. Calcaneovalgus deformity often causes toeing-out and equinovarus and metatarsus varus deformities cause toeing-in. Bow legs are commonly associated with toeing-in, while knock-knees, usually, although not necessarily, are associated with toeing-out. Muscle imbalance with paralysis of the internal rotators of the hip following poliomyelitis will usually cause toeing-out and in spastic paralysis with overactivity of the internal rotators, toeing-in results. Tibal torsion, likewise, is a well understood entity although accurate measurement is clinically, at times, rather difficult. This subject was well investigated by Nachlas in 1934 and more recently by Hutter and Scott. Kite, Howorth, and Knight have shown that many abnormal gaits result from a combination of factors.

During the past eight years a series of seventy-two children have been studied whose lower extremities have twisted either inward or outward in the presence of relatively normal feet and tibiae. The most significant finding on physical examination was a definite difference in the degree of internal and external rotation of the hips. Through roentgenographic study these children have been found to have abnormal femoral torsion.

*Read at the Annual Meeting of The American Academy of Orthopaedic Surgeons, New York, N. Y., February 6, 1958.

TABLE I

projected inclination	projected anteversion 0	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90
80	0	3	7	12	16	20	24	29	33	38	43	47	53	59	65	71	77	84	
90	0	4	9	13	17	22	27	31	36	41	46	51	56	62	67	73	79	84	
95	0	5	9	14	18	23	28	32	37	42	47	52	58	63	68	74	79	85	
100	0	5	10	14	19	24	29	34	39	44	49	54	59	64	69	74	80	85	90
105	0	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90
110	0	5	10	16	21	26	31	36	41	46	51	56	61	66	71	76	80	85	90
115	0	5	11	16	22	27	32	38	43	48	53	57	62	67	72	76	81	85	90
120	0	6	11	17	23	28	34	39	44	49	54	59	63	68	72	77	81	86	90
125	0	6	12	18	24	30	35	41	46	51	56	60	65	69	73	78	82	86	90
130	0	6	13	19	25	31	37	42	47	52	57	62	66	70	74	78	82	86	90
135	0	7	14	20	27	33	38	44	48	54	58	63	67	71	75	79	83	86	90
137 → 140	0	7	14	21	28	34	39 40	46	50	56	60	64	68	72	76	80	83	87	90
145	0	8	16	23	30	36	42	48	53	58	62	66	70	74	77	80	84	87	90
150	0	9	17	25	32	39	45	50	55	60	64	68	72	75	78	81	84	87	90
155	0	10	19	27	35	42	48	54	58	63	67	70	73	77	79	82	85	87	90
160	0	11	22	31	39	46	52	58	62	65	70	73	76	78	81	83	86	88	90
165	0	13	26	36	45	52	57	62	66	70	73	76	78	80	82	84	86	88	90
170	0	18	33	45	53	60	65	69	72	75	77	79	81	83	84	86	87	89	90
175	0	29	48	59	67	71	75	77	79	81	82	84	85	86	87	88	88	89	90
180	0	90	90	90	90	90	90	90	90	90	90	90	90	90	90	90	90	90	90

ANTEVERSION

DEFINITION

Since torsion or anteversion of the femoral neck is not always well understood, some explanation is appropriate. The angle of inclination of the femoral neck is the angle formed by the intersection of the shaft axis with a line through the femoral neck or the neck axis. The transcondylar axis, a horizontal or transverse line through the femoral condyles, and the femoral-shaft axis define a plane called the transcondylar plane. If one looks up the shaft of the femur from the knee, one sees the angle of anteversion. It is the angle made by the intersection of the transcondylar plane and the neck axis. Stated another way, this angle is a measure of the twist of the shaft of the femur which directs the head and neck forward in relation to the plane of the femoral condyles. If the head and neck are directed backward with reference to this plane it is called retroversion.

PROBLEM

The angle of anteversion has been determined accurately in adult specimens by various authors who have determined averages which, depending upon the author, have ranged between 8 and 15 degrees [4,5,9,14,15,19]. Because of the paucity of femora available for study in infants and children, the amount of femoral torsion in these groups is not known. Several methods of measuring this angle roentgenographically have been described [3,12,16]. Two of them require a frame which holds the thigh in 90 degrees of flexion and a known degree of abduction. The x-ray tube is placed thirty-six inches above the pubic symphysis and the cassette under the pelvis. The baseline of the roentgenogram is used to represent the transcondylar plane; if a line running parallel to this is drawn in the region of the femoral shaft, its intersection with the neck axis will give us the projected angle of anteversion. A second roentgenogram must be made to obtain the true angle of anteversion. This is the commonly used anteroposterior view of the hip. The roentgenogram must be made with the thighs in neutral rotation which can be done by flexing the knees over the end of the table. The angle as measured is the projected angle of inclination. The geometrical relationship of these two projected angles has been worked out mathematically by Dr. Charles T. Ryder

and Dr. Robert L. Taylor[16] with the result that a table (Table I) was set up which makes it easy to determine the angle of anteversion. It is based on the fact that if two roentgenographic projections of the femoral neck are known, the true angle of declination or inclination can be determined by mathematical means. In order to use the table, one merely intersects the column headed by projected anteversion with the column marked projected inclination and interpolates as necessary. For example, a projected anteversion of 30 degrees and a projected inclination of 137 degrees would give a true anteversion value of 39 degrees. The other methods of calculating the angle of anteversion make use of these two angles in essentially the same manner. Shands and Steele have recently published results of a study of femoral torsion in normal children. These are almost identical to those found in this study.

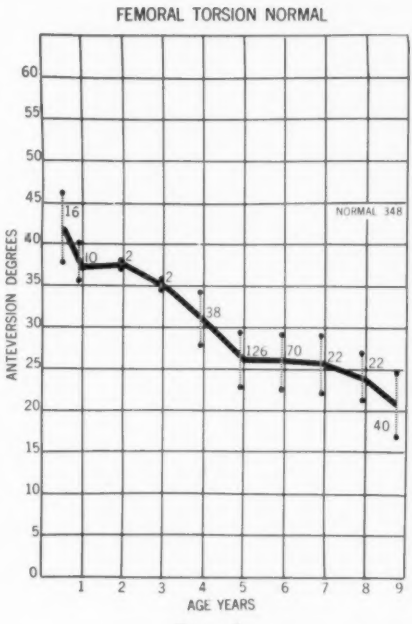


CHART I

The solid line represents the mean; the vertical lines represent standard deviation.

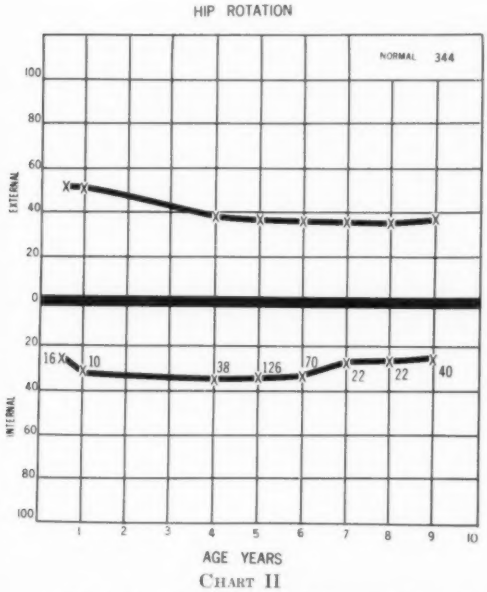


CHART II

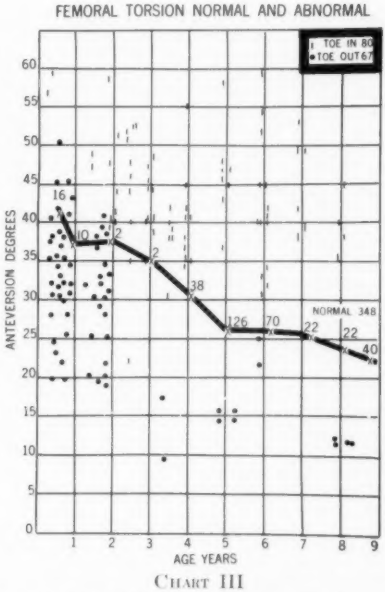


CHART III

Chart II: Hip rotation in 344 normal hips. Figures on the chart designate the number of hips examined. Rotation in four hips early in the series was not measured.

Chart III: Spot graph showing toeing-in and toeing-out in relation to normal curve.

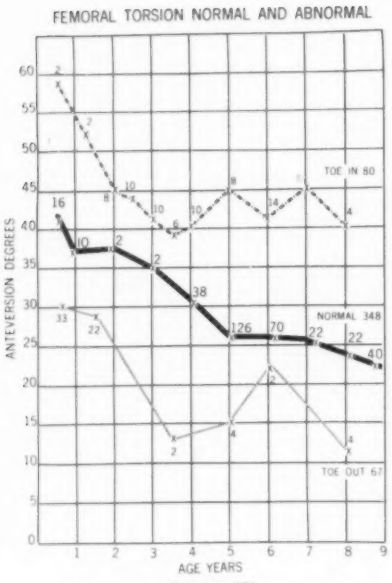


CHART IV

Figures indicate number of hips x-rayed.

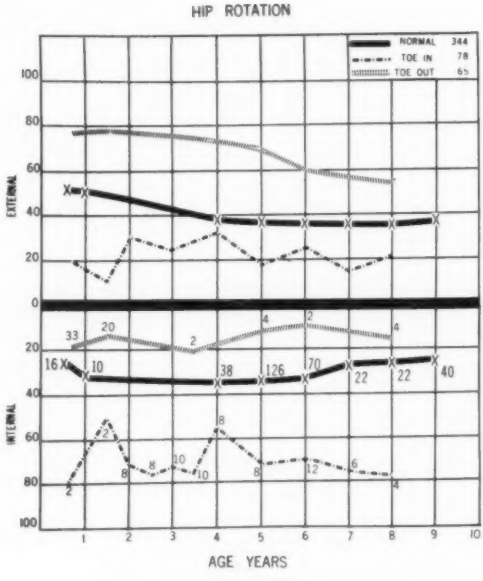


CHART V

Rotation of normal and abnormal hips.

NORMAL SERIES OF FEMORAL TORSION

In addition to determining the femoral torsion in this group of seventy-two abnormal patients, it was necessary to get a baseline of normal values by means of the same methods. This was done during 1954 and 1955 by obtaining appropriate roentgenograms of 174 children between the ages of six months and nine years who sat or walked without toeing-in or toeing-out. These children and infants were obtained from well-baby clinics, were hospital patients who had conditions not related to the lower extremities, or were normal school children. Roentgenograms were made to determine the degree of femoral torsion; the range of rotation of the hips was estimated by examination of each child with the hips in full extension. Femoral torsion is three to four times greater during the first year of life than in adulthood then gradually tapers off. In Chart I the solid line represents the mean of the group whereas the vertical lines represent the standard deviation. The rotation of the normal series of 348 hips, however, did not vary a great deal with age (Chart II).

ABNORMAL SERIES

Chart III shows the normal angle of anteversion in a solid black line with all the abnormal hips as they relate to it. Although a number of patients toeing-in and toeing-out fall within the standard deviation of the normal series, the mean of the patients toeing-in and toeing-out is far apart. Some of the groups have been too small to evaluate the statistical significance but where possible this has been done. The range of rotation of the abnormal hips has been measured and the results have been superimposed on Chart II (Chart V). While external rotation was 60 to 80 degrees and internal rotation was less than 20 degrees in patients toeing-out, internal rotation was 60 to 80 degrees and external rotation was 10 to 30 degrees in patients toeing-in.

TREATMENT AND RESULTS

The type of treatment used depended upon the severity of the condition and age of the patient. Children over five years of age showed little or no improve-

FIG. 1

Modified flexion abduction frame. Girl's femora and tibiae are strapped at 90 degrees.

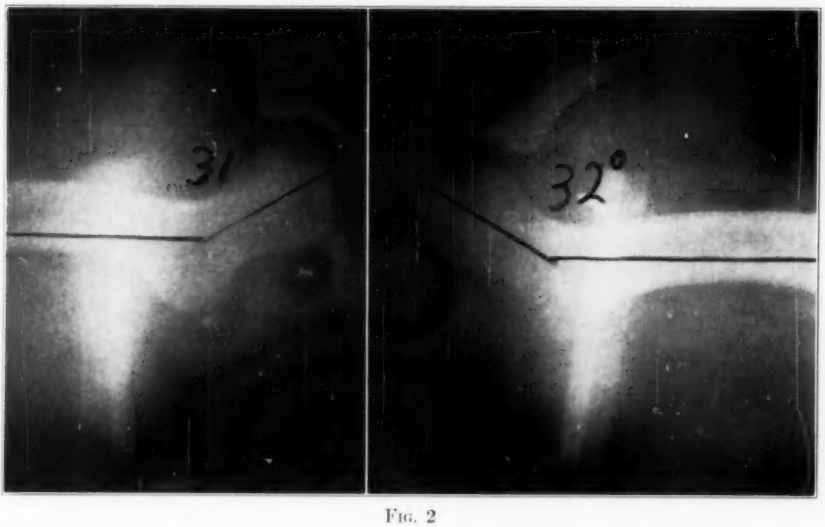


FIG. 2

Roentgenograms of a child's hips after being positioned in the flexion abduction frame.

ment with Denis Browne splints. The younger the child, the more rapid is the response to these splints. The average length of treatment with Denis Browne splints was four to eight months. Most of the patients with mild cases were either

TABLE II

Type of Treatment		Results	
Toeing-in: 37 patients			
Night splints	21	Satisfactory	9
		Unsatisfactory	11
		Over 5 yrs. old	2
		Treatment not tolerated	4
		Little's disease	1
		No response after 6 to 12 mos. stretching	4
		Lost to follow-up	1
			21
Exercises	1	Unsatisfactory (too old)	1
Wedges	1	Satisfactory	1
No Treatment	14	Satisfactory	12
		Unsatisfactory (cerebral palsy)	2
			37
Toeing-out: 35 patients			
Night splints	22	Satisfactory	14
		Unsatisfactory	5
		Treatment not tolerated	3
		Paralysis	2
		Lost to follow-up	3
			22
Wedges	1	Satisfactory	1
Exercises	4	Satisfactory	3
		Lost to follow-up	1
No treatment	8	Satisfactory	5
		Unsatisfactory (brain damage)	3
			35

just observed or treated with wedges. Only one patient underwent surgery. This was a boy six years of age who had been treated for a year with Denis Browne splints for toeing-in without improvement. He was doing well nine months after bilateral supracondylar osteotomy.

Table II summarizes the type of treatment and the results obtained in the seventy-two patients. If both mother and physician were satisfied with the result, the result was classified *satisfactory*. On the other hand, if either mother or physician felt the child toed-in or out to any degree, the result was considered *unsatisfactory*. An attempt was made to make roentgenograms after treatment to see if the femoral torsion approached the normal. The impression was gained that most of them did; there was an insufficient number of cases to be of statistical significance. This study should be carried out more thoroughly in the future.

DISCUSSION

The cause of abnormal femoral or tibial torsion is not known. Fitzhugh, in reviewing the sleeping positions of children, noted that of 100 infants who slept in the knee-chest position, 84 per cent had a deviation of the lower extremities, either inward or outward, of more than 10 degrees. Recently Arkin and Katz have produced torsion in the hind legs of rabbits by the application of plaster casts. Among other things, they showed that the force of gravity was the prime factor in the causation of the torsion. However, there is some evidence indicating that the femur fails to derotate *in utero* resulting in a persistent fetal position [18].

Of the seventy-two children in this series, in twenty-one (29 per cent) there

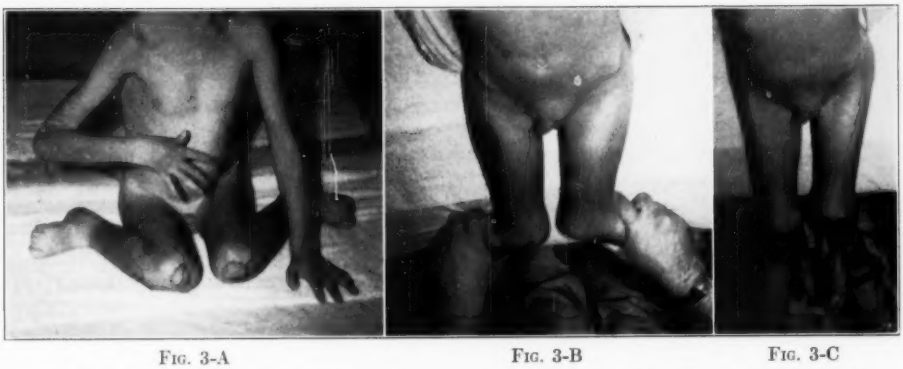


FIG. 3-A FIG. 3-B FIG. 3-C

Fig. 3-A: C. A., a seven-year-old boy in a mental institution, habitually sat with his feet under him.

Fig. 3-B: Maximum internal rotation of the hips is 75 degrees.

Fig. 3-C: Maximum external rotation of the hips is 5 to 10 degrees.

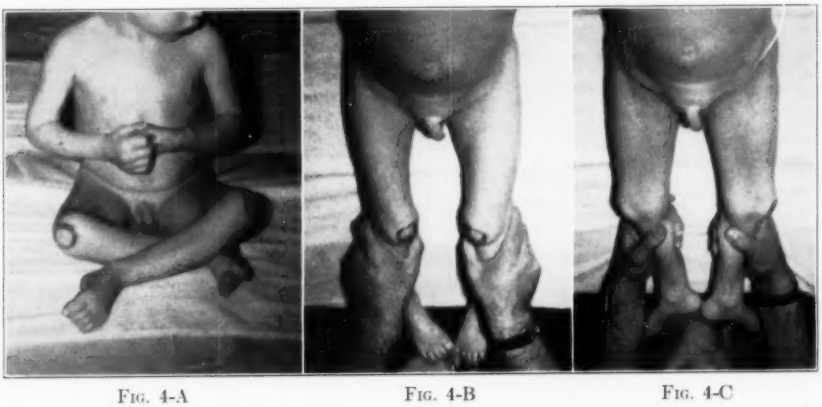


FIG. 4-A FIG. 4-B FIG. 4-C

Fig. 4-A: P., a five-year-old child with chronic brain syndrome, sat in the tailor's position. If his legs were straigthened, he would always revert to this position.

Fig. 4-B: Maximum internal rotation of the hips is 10 degrees.

Fig. 4-C: Maximum external rotation of the hips is 80 degrees.

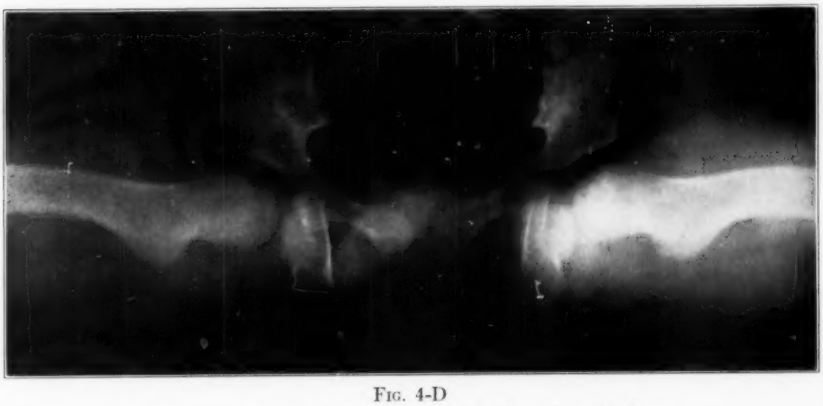


FIG. 4-D

Roentgenogram reveals anteversion to be less than 10 degrees.

was history of similar deformities in the parents or siblings. In fifty-four (75 per cent) there was history of sleeping, during the first year of life, in a position that would, if not produce the condition, at least aggravate it. Of the remaining 25 per cent, sleeping position was unknown in 15 per cent because they were early in the series and could not be located for follow-up study.

The following two patients bear out the postnatal malposition theory so well they are presented in more detail. Both were in a mental institution, each with a diagnosis of cerebral atrophy. Neither could talk nor walk. Their positions of sitting and sleeping, however, were opposite. The first one, C. A., a seven-year-old boy, sat with his feet under him (Figs. 3-A, 3-B, and 3-C). Internal rotation of the hips was 75 degrees and external rotation only 5 to 10 degrees. The angle of anteversion was 50 degrees on the right and 53 degrees on the left. The five-year-old child in the next bed sat in the tailor's position (Figs. 4-A, 4-B, and 4-C). If his legs were straightened, he would always revert to this position. Internal rotation of the hip was 10 degrees and external rotation 80 degrees. One would expect that five years of sitting would derotate the femora to the point where there was little or no anteversion. Figure 4-D shows this to be the case.

According to Wolff's law, these bones should rotate or derotate according to the stresses and pressures to which they are habitually subjected. The postnatal malposition in these children would seem to be one of the important etiological factors, with the twisting, either inward or outward of the tibia or femur or both, directly related to this malposition.

REFERENCES

1. Appleton, A. B.: Positional Deformities and Bone Growth. An Experimental Study. Lancet, **1**: 451-454, 1934.
2. Arkin, A. M., and Katz, J. F.: Effects of Pressure on Epiphyseal Growth. The Mechanism of Plasticity of Growing Bone. J. Bone and Joint Surg., **38-A**: 1056-1076, Oct. 1956.
3. Dunlap, Knox; Shands, A. R., Jr.; Hollister, L. C.; Gaul, J. S., Jr.; and Streit, H. A.: A New Method for Determination of Torsion of the Femur. J. Bone and Joint Surg., **35-A**: 289-311, Apr. 1953.
4. Durham, H. A.: Anteversion of the Femoral Neck in the Normal Femur. J. Am. Med Assn., **65**: 223-224, 1915.
5. Eleftman, Herbert: Torsion of the Lower Extremity. Am. J. Phys. Anthropol., **3**: 255-265, 1945.
6. Fitzhugh, M. L.: Faulty Alignment of the Feet and Legs in Infancy and Childhood. Physiother. Rev., **21**: 239-245, 1941.
7. Howorth, M. B.: A Textbook of Orthopedics. Philadelphia, W. B. Saunders Co., 1952.
8. Hutter, C. G., and Scott, Walter: Tibial Torsion. J. Bone and Joint Surg., **31-A**: 511-518, July 1949.
9. Kingsley, P. C., and Olmsted, K. L.: A Study to Determine the Angle of Anteversion of the Neck of the Femur. J. Bone and Joint Surg., **30-A**: 745-751, July 1948.
10. Kite, J. H.: Torsion of the Lower Extremities in Small Children. J. Bone and Joint Surg., **36-A**: 511-520, June 1954.
11. Knight, R. A.: Developmental Deformities of the Lower Extremities. J. Bone and Joint Surg., **36-A**: 521-527, June 1954.
12. Magilligan, D. J.: Calculation of the Angle of Anteversion by Means of Horizontal Lateral Roentgenography. J. Bone and Joint Surg., **38-A**: 1231-1246, Dec. 1956.
13. Nachlas, I. W.: Medial Torsion of the Leg. Arch. Surg., **28**: 909-919, 1934.
14. Parsons, F. G.: The Characters of the English Thigh-Bone. J. Anat. and Physiol., **48**: 238-267, 1951.
15. Pick, J. W.; Stack, J. K.; and Anson, B. J.: Measurements on the Human Femur. I. Lengths, Diameters and Angles. Quart. Bull. Northwestern Univ. Med. Sch., **15**: 281-290, 1941.
16. Ryder, C. T., and Crane, Lawrence: Measuring Femoral Anteversion: The Problem and a Method. J. Bone and Joint Surg., **35-A**: 321-328, Apr. 1953.
17. Shands, A. R., Jr., and Steele, M. K.: Torsion of the Femur. J. Bone and Joint Surg., **40-A**: 803-816, July 1958.
18. Somerville, E. W.: Persistent Foetal Alignment of the Hip. J. Bone and Joint Surg., **39-B**: 107-113, Feb. 1957.
19. Soutter, Robert, and Bradford, E. H.: Twists in Normal and in Congenital Dislocated Femora. New York Med. J., **78**: 1071-1077, 1903.

Capsular Arthroplasty in Paralytic Dislocation of the Hip

A Preliminary Report

BY S. L. WEISSMAN, M.D., TEL-AVIV, ISRAEL

From Tel-Hashomer Government Hospital, Tel-Aviv

Paralytic dislocation of the hip following poliomyelitis is relatively uncommon. Indeed, considering how frequently patients show paralysis of the muscles around the hip without dislocation, the incidence of this complication is low.

It is beyond the scope of this paper to discuss the pathogenesis of paralytic dislocation of the hip. However, dislocation is a complication which occurs in some paralytic hips and greatly increases the therapeutic problems encountered in their management.

Conservative treatment accomplishes little in these dislocations; although reduction is easily achieved, it is rarely maintained. Shelf stabilization, an operative procedure which has been used extensively, has not proved wholly satisfactory [3]. The correction of muscle imbalance by tendon transplantation may be of value in preventing dislocation or in maintaining reduction of paralytic dislocation in its early stages, that is, when the head still is in partial contact with the acetabulum and the acetabulum has not yet undergone secondary atrophy. It may be questioned, however, whether these procedures can cope with a complete dislocation of long standing.

Recently Jones and Mueller advocated correction of valgus deformity of the femoral neck by subtrochanteric osteotomy to prevent paralytic dislocation. According to Jones, this treatment is also of value in maintaining reduction in those instances in which reduction by manipulation is achieved with ease and in which the acetabulum preserves sufficient depth to accommodate the femoral head. To be effective the subtrochanteric osteotomy must correct anteversion and valgus deformity of the femoral neck [5].

Tendon transplantation, osteotomy, and correction of acetabular insufficiency may also be combined successfully, as was shown by Fleming.

However, for the fully established dislocation, in which the head has lost all contact with the acetabulum and the latter has undergone atrophy with resultant instability and pain, the only solution offered in the past has been arthrodesis of the hip [3]. Arthrodesis could be performed only on adults and the problem of advanced paralytic dislocation in children has remained unsolved.

It is the purpose of this paper to present evidence that capsular arthroplasty of the hip, devised by Colonna in 1930 for the treatment of congenital dislocation of the hip, can be used in children in whom paralytic dislocation of the hip developed following poliomyelitis. This particular indication for the operation has not been encountered in the literature.

CLINICAL MATERIAL

During the last three years six children with paralytic dislocation of the hip have been treated by capsular arthroplasty (Table I).

Their ages at operation ranged from three to eight years. Three of these patients were under our care from the onset of paralysis and gradual development of the dislocation was followed. The other three came under our care when dislocation was already complete.

The degree of muscle involvement is summarized in detail in Table II. The usual pattern of paralysis of the hip muscles in these patients included a more or

TABLE I

Case	Patient	Sex	Poliomyelitis at the age of	Age at First Examination (*Years*)	Age at Operation (*Years*)	Hip Dislocated	Condition of Opposite Hip	Other Deformities
1	M.R.	F	2 yrs., 4 mos.	5	6	Right	Normal	Flail right foot
2	A.B.	F	7 mos.	4	4½	Right	Abduction contracture; fixed pelvic obliquity	Equinovalgus deformity of both feet; flexion contracture of both knees
3	K.A.	M	4 yrs.	4	8	Right	Normal	Flail right foot
4	Y.E.	M	11 mos.	2½	3	Left; all muscles paralyzed but slight power in tensor fasciae latae; flexion contracture	Normal	Flail left knee; flail left foot
5	A.N.	M	1 yr.	1	3	Left	Abduction contracture; fixed pelvic obliquity	Flexion contracture of right knee; equinus deformity of both feet
6	M.Ra.	F	1 yr., 6 mos.	2	4½	Left	Normal	Flail left foot

less pronounced weakness of the hip abductors, extensors, and rotators with normal adductors and fair flexors.

Two patients (Cases 2 and 5) had had fixed pelvic obliquity associated with abduction contracture of the opposite hip. In one patient (Case 4) dislocation developed in a totally paralyzed lower extremity; the tensor fasciae latae was the only muscle with any remaining power.

Treatment before arthroplasty had consisted in physical therapy and the use of long braces provided with a pelvic ring and a freely movable hinge joint at the hip.

In the two children with pelvic obliquity the abduction contracture of the opposite hip was corrected surgically by fasciotomy of the iliotibial band.

INDICATIONS

Although fourteen children with paralytic dislocation of the hip were followed during the last few years, only six were treated by capsular arthroplasty. The remaining eight children were not operated upon because surgery was not indicated. Only children over three years and under ten years of age were considered suitable for arthroplasty. The operation was advised only in patients with fully established dislocation when the head of the femur had lost all contact with the acetabulum and the acetabulum was atrophied and shallow.

Preoperative arthrograms were made of all but one patient. These studies gave valuable information about the degree of stretching of the capsule, the state of the limbus, and the presence or absence of a narrow capsular isthmus. Furthermore, arthrography in different degrees of abduction and rotation allowed assessment of the adequacy of the reduction.

In all patients, the cartilaginous limbus was markedly atrophic and the cap-

TABLE I

Roentgenographic Findings	Capsular Arthroplasty	Supplementary Operations
Slight atrophy of acetabulum; valgus deformity and anteversion of femoral neck; arthrogram revealed atrophic limbus and absence of isthmus	May 31, 1955	Concomitant adductor tenotomy; derotation osteotomy of femur (6 wks. later)
Marked atrophy of acetabulum; valgus deformity and anteversion of femoral neck; arthrographic findings as in Case 1	Sept. 13, 1955	Concomitant adductor tenotomy; derotation osteotomy of femur (6 wks. later)
Valgus deformity and anteversion of femoral neck	Feb. 28, 1956	Concomitant adductor tenotomy; derotation osteotomy of femur (6 wks. later)
Slight atrophy of acetabulum; arthrographic findings as in Case 1	Apr. 19, 1956	Transference of tensor fasciae latae to insertion of glutaeus maximus
Marked atrophy of acetabulum; valgus deformity and anteversion of femoral neck; arthrographic findings as in Case 1	Apr. 24, 1956	Concomitant adductor tenotomy; derotation osteotomy of femur (6 wks. later)
Slight atrophy of acetabulum; valgus deformity and anteversion of femoral neck; arthrographic findings as in Case 1	Jan. 3, 1957	Concomitant adductor tenotomy; derotation osteotomy of femur (6 wks. later)

sular isthmus sufficiently wide to allow easy reduction of the femoral head into the socket. However, reduction could be achieved only in a position of at least 45 degrees of abduction, whether the hip was in extension and internal rotation or in flexion and external rotation. In the position of extension and internal rotation a small pool of contrast medium remained at the bottom of the acetabulum; this pool was absent when the hip was put into flexion and external rotation (Fig. 1).

TABLE II

MUSCLE GRADING

Muscles	Case 1	Case 2	Case 3	Case 4	Case 5	Case 6
Hip						
Flexors	Fair	Fair	Fair	None	Fair	Fair
Extensors	Trace	Trace	Poor	None	None	None
Abductors	Poor	Trace	Poor	None	Poor	Poor
Adductors	Normal	Normal	Normal	None	Normal	Normal
External Rotators	Fair	Poor	Fair	None	Poor	Poor
Internal Rotators	Poor	None	Poor	None	Poor	Poor
Sartorius	Poor	None	None	None	Poor	Poor
Tensor Fasciae Latae	Fair	Poor	Poor	Poor	Fair	Fair
Knee						
Extensors	Good	Fair	Good	None	Fair	Poor
Flexors	Fair	Good	Poor	None	Good	Fair

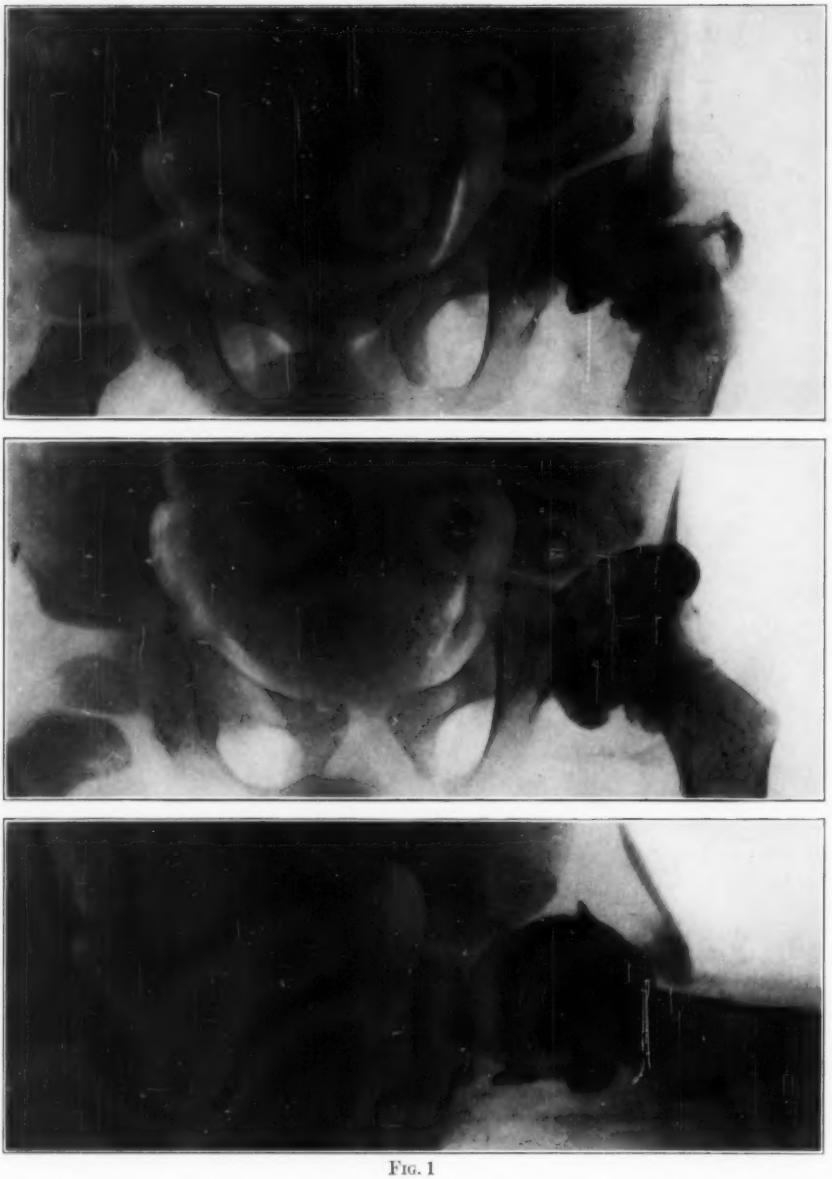


FIG. 1

Case 5. Typical arthrogram of a paralytic dislocation. The absence of capsular constriction and the atrophy of the cartilaginous limbus are obvious. The middle arthrogram was made with the hip held in maximal internal rotation and 45 degrees of abduction. In this position the head does not reach the bottom of the acetabulum and a pool of contrast fluid accumulates between the femoral head and the acetabular wall. This pool disappears when the hip is put in the frog-leg position indicating complete reduction (lower picture).

The significance of these findings may be summarized as follows. Reduction was achieved with ease in all instances since there was no capsular constriction. However, complete reduction was achieved only in flexion and external rotation (the frog-leg position). In extension and full internal rotation, wide abduction

FIG. 2-A

Case 1. Paralytic dislocation of the right hip in a six-year-old girl.

FIG. 2-B

Two and a half years after capsular arthroplasty.

was necessary to keep the femoral head in the socket, but even then the head did not reach the bottom of the acetabulum.

It might be supposed that subtrochanteric derotation osteotomy to correct anteversion, combined with angulation of the shaft to produce a moderate degree of varus position of the femoral neck, would maintain the head in the acetabulum. However, the reduction so achieved would have been incomplete because the head would not reach the bottom of the acetabulum as shown by arthrography. With osteotomy alone, the incompleteness of the reduction, as well as the shallowness of the acetabulum and atrophy of the cartilaginous limbus, would make the future stability of the hip questionable. An atrophied or apparently absent limbus was a constant finding at operation.

The data supplied by arthrography further define the indications previously mentioned for arthroplasty, by demonstrating a shallow acetabulum, an atrophic limbus, and failure of the femoral head to seat in the acetabulum even with the hip in extension and full internal rotation to offset anteversion.

OPERATIVE TECHNIQUE

The technique described by Colonna was followed with the exception of pre-

TABLE III
RESULTS

Case	Length of Follow-up Period	Stability	Range of Movements: Flexion Normal: 120 (*Active*)	(*Passive*)	Extension Normal: 20 (*Active*)	(*Passive*)	Abduction Normal: 45 (*Active*)	(*Passive*)	Adduction Normal: 45 (*Active*)	(*Passive*)
1	3 yrs.	Good	90	90		20	45	45	35	35
2	2 yrs., 9 mos.	Good	80	80		20	10	20	45	45
3	2 yrs., 4 mos.	Good	90	90	10	20	45	45	40	40
4	2 yrs., 2 mos.	Good		120		20		45		45
5	2 yrs., 2 mos.	Good	80	80		20	45	45	30	30
6	1 yr., 6 mos.	Good	80	80			30	30	45	45

liminary continuous traction which was omitted in view of paralysis. Adductor tenotomy was performed concomitantly with arthroplasty, and supracondylar osteotomy of the femur, advised by Colonna, was performed six weeks later.

In one patient (Case 4), the tensor fasciae latae, the only active muscle in an otherwise flail hip, was detached from the iliotibial band and fixed to the insertion of the glutaeus maximus muscle on the femur. This was done merely to abolish a deforming factor, with no idea of achieving useful function. No active movement of the hip in any direction could be detected at follow-up examinations. Moreover, no derotation osteotomy was performed upon this patient, since there was no anteversion of the femoral neck.

RESULTS

Results were judged by stability, range of movement, and gait (Table III).

FIG. 3-A

Case 2. Paralytic dislocation of the right hip in a girl four and a half years old.

TABLE III
RESULTS

in Degrees Internal Rotation Normal: 45 (*Active*)	(*Passive*)	External Rotation Normal: 45 (*Active*)	(*Passive*)	Gait	Length of Time Patient Had Walked at Last Examination (*Months*)
20	45	45	45	Glutaeus maximus limp	30
		45	45	Starting to walk with braces and crutches	8
10	10	30	30	Slight glutaeus maximus limp	22
	45		45	Walks correctly with a brace	22
20	30	20	30	Walks with braces and crutches	14
10	10	10	10	Slight limp	12

The stability achieved by capsular arthroplasty has so far proved remarkable in all patients and no instance of redislocation has occurred (Figs. 2 through 7). Walking ability has greatly improved and in patients with partial paralysis, braces were removed.

The restoration of motion after arthroplasty was thought to be dependent upon available muscle power. It was feared, therefore, that paralysis of the hip muscles would lead to subsequent joint stiffness. This was disproved by the results. The most striking example was found in the patient in whom dislocation developed in a totally flail limb (Case 4). Although without active motion, the hip could be freely moved, passively, through a full range of motion when examined one and a half years after operation.

The minimal range of motion was attained in Cases 2 and 5. In contrast to

FIG. 3-B

Two years after capsular arthroplasty.

FIG. 4-A

Case 3. Paralytic dislocation of the right hip in a boy aged eight years.

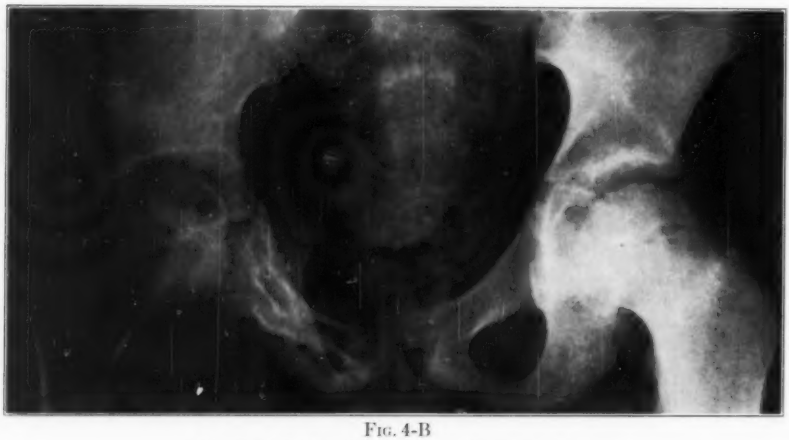


FIG. 4-B

One and a half years after capsular arthroplasty.

FIG. 5-A

Case 4. Paralytic dislocation of the left hip in a three-year-old boy.

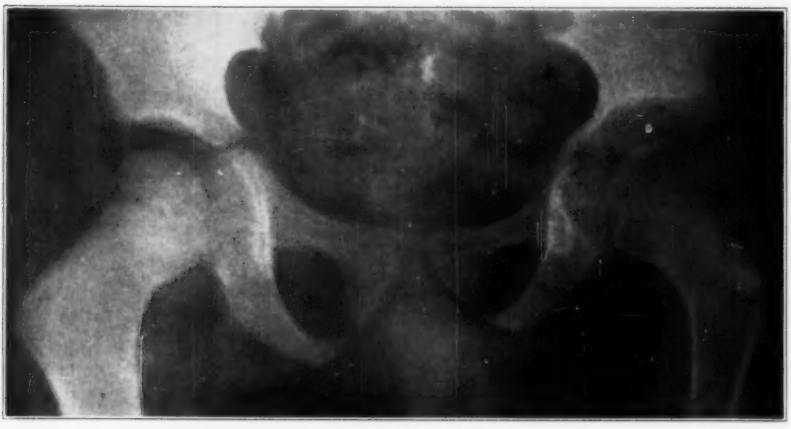


FIG. 5-B

One and a half years after capsular arthroplasty.

the remaining children these two patients had severe involvement of both lower extremities. In Case 5 there was paralysis of the left upper extremity also. Moreover, both of these patients had pelvic obliquity due to abduction contracture of the contralateral hip with concomitant deformities of the knees and feet. Consequently, the rehabilitation program was fairly extensive. In one (Case 5) all reconstructive procedures were completed and, at the time of writing, the patient's ability to walk was improving with increasing joint mobility. In the other patient (Case 2), the reconstructive procedures were delayed by repeated pulmonary infections and were resumed only recently, after a delay of over one year. For these reasons the child has only started to walk, with braces and crutches, at the time of writing.

Even with these drawbacks, the range of movement recovered in these two patients may be considered satisfactory (Table III) and further progress may be anticipated.

In the remaining three patients (Cases 1, 3, and 6) in whom the unaffected contralateral extremity allowed early resumption of normal activity, the range of movement following arthroplasty was normal.

In most of the fully rehabilitated patients with effective muscle power about the hip, passive mobility slightly exceeded active movement. This again allays any apprehension that paralysis may lead to joint stiffness. It may even be inferred that the absence of muscle power and protective spasm favored joint mobility after arthroplasty.

In regard to gait, it must be stated that limp, although greatly improved, was not abolished by the operation. Persistence of limp was due to weakness of the glutaeus maximus and glutaeus medius for, as might be expected, the paralytic pattern remained essentially unchanged after the operation. However, improvement of gait through stabilization of the femoral head was quite noticeable.

DISCUSSION

A greater number of patients and a longer follow-up period are needed in order to evaluate precisely the indications for capsular arthroplasty in patients with paralytic dislocation of the hip. It is believed that the procedure is undoubtedly of value.

The results at the time of this preliminary report indicate that capsular arthroplasty accomplishes its purpose by ensuring both stability and mobility of the hip. Following operation there was noticeable improvement in limp. Despite paralysis of the hip muscles, no loss of joint motion occurred.

FIG. 6-A

Case 5. Paralytic dislocation of the left hip in a boy aged three years.

FIG. 6-B

One and a half years after capsular arthroplasty.

Adductor tenotomy and derotation osteotomy were performed on five of these patients. The importance of these ancillary procedures in securing the final result must be acknowledged, but it seems unlikely that these procedures alone, without arthroplasty, would have given the same results. In this connection, it is of interest that in two patients, not included in this report, adductor tenotomy was performed during the early stages of the development of the dislocation but this did not stop further progress. These two patients are still too young for capsular arthroplasty and are being followed.

In evaluating the merits of capsular arthroplasty in paralytic dislocation it should be stressed that this procedure, by correcting the dislocation, eliminates severe disability but it does not solve all the problems caused by paralysis of the hip muscles. It should also be remembered that the procedure is applicable

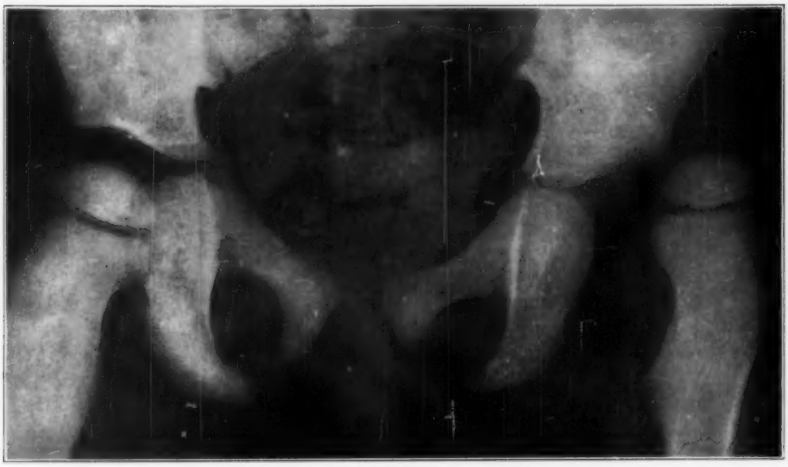


FIG. 7-A

Case 6. Paralytic dislocation of the left hip in a girl four and a half years old.

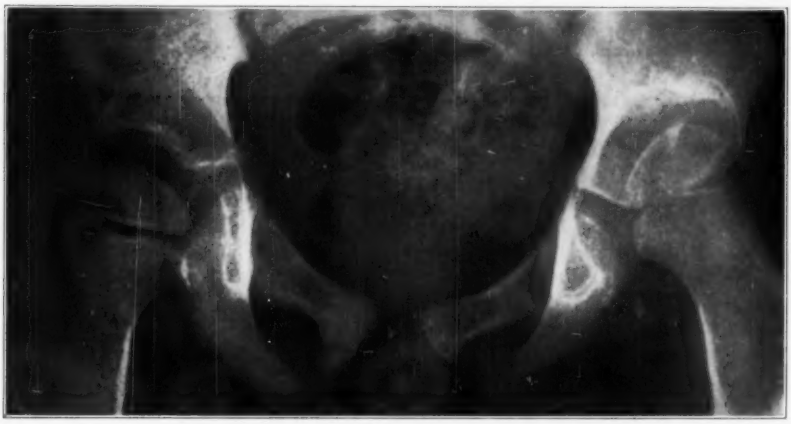


FIG. 7-B

One year after capsular arthroplasty.

only to children from three to ten years old. It was precisely within this age group that the need for a reliable procedure to treat established dislocation was felt. Capsular arthroplasty seems to meet the requirements.

REFERENCES

1. COLONNA, P. C.: Capsular Arthroplasty for Congenital Dislocation of the Hip. A Two-Stage Procedure. J. Bone and Joint Surg., **35-A:** 179-197, Jan. 1953.
2. FLEMING, J. L.: Iliopsoas Transplant-Femoral Osteotomy for Paralytic Dislocation. *In* Proceedings, The American Academy of Orthopaedic Surgeons. J. Bone and Joint Surg., **39-A:** 697, June 1957.
3. HALLOCK, HALFORD: Arthrodesis of the Hip for Instability and Pain in Poliomyelitis. J. Bone and Joint Surg., **32-A:** 904-909, Oct. 1950.
4. JONES, G. B.: Paralytic Dislocation of the Hip. J. Bone and Joint Surg., **36-B:** 375-384, Aug. 1954.
5. MUELLER, M. E.: Die hüftnahen Femurosteotomien. Unter Berücksichtigung der Form, Funktion und Beanspruchung des Hüftgelenkes, pp. 119-128, Stuttgart, George Thieme, 1957.

Prevention of Acquired Dislocation of the Hip in Cerebral Palsy*

BY WINTHROP M. PHELPS, M.D., BALTIMORE, MARYLAND

This paper deals entirely with the methods for prevention of acquired dislocation of the hip in patients with cerebral palsy. The various procedures used for correction of the dislocation once it has occurred are not germane to this discussion.

At best, it is difficult to assess the value of any preventive measure. It can never be proved in any given patient that a condition for which a preventive measure was instituted would in fact have developed if this preventive measure had never been instituted. However, by careful evaluation and observation of the apparent causes of the dislocations of the hip in cerebral palsy, it was possible to institute effective and specific preventive measures.

Congenital dislocation of the hip has been the subject of innumerable papers throughout the world for many years. Acquired dislocations of the hip due to both trauma and disease are also well documented. Acquired dislocation of the hip in cerebral palsy was referred to briefly by some authors and reported statistically by Gherlinzoni, Mathews, and Tachdjian and Minear. The incidence reported was 4.6 per cent, 2.6 per cent, and 4.24 per cent, respectively. At the Children's Rehabilitation Institute for Cerebral Palsy, Reisterstown, Maryland, and at the Matheney School, Peapack, New Jersey, the incidence of dislocation has been approximately 17 per cent. As noted by Tachdjian and Minear dislocations occur most commonly in patients with spasticity and rigidity due, presumably, to the constant, abnormal muscle pull. In patients with mild cerebral palsy the incidence of hip dislocation is very low.

A careful study of the roentgenograms of the hips of children with cerebral palsy discloses the existence of several types of dislocation which are quite distinct from each other. These different types of dislocation are characterized by changes in the femur including variations in the angle of the neck and in the degree of femoral torsion, and by changes in the shape and size of the acetabulum. The problem, therefore, is to determine what causes these changes.

Patients with cerebral palsy—a neuromuscular disturbance and not primarily a disease of the osseous system—should show no greater incidence of congenital dislocation or dysplasia of the hip than the general population. The frequency of congenital dislocation of the hip varies geographically and racially; Hass quoted many statistical studies showing the incidence to vary from 2.76 to nineteen per thousand or a maximum incidence of 1.9 per cent of normal children. This is in striking contrast to the incidence of hip dislocation in children with severe cerebral palsy which, as noted previously, may be as high as 17 per cent. There is no indication that the incidence of dysplasia or congenital dislocation of the hip is any higher in children with cerebral palsy than among the population at large. I have found that serial roentgenograms of the hips of some children with cerebral palsy will show normal hips initially with subsequent development of frank dislocation. In these instances it would appear that cerebral palsy is in some way the cause of the dislocation.

Certainly, in children with cerebral palsy the stresses on the bones are very different from those in normal children. Not only are there abnormal muscle pulls

* Read at the Annual Meeting of The American Orthopaedic Association, Hot Springs, Virginia, June 27, 1957.

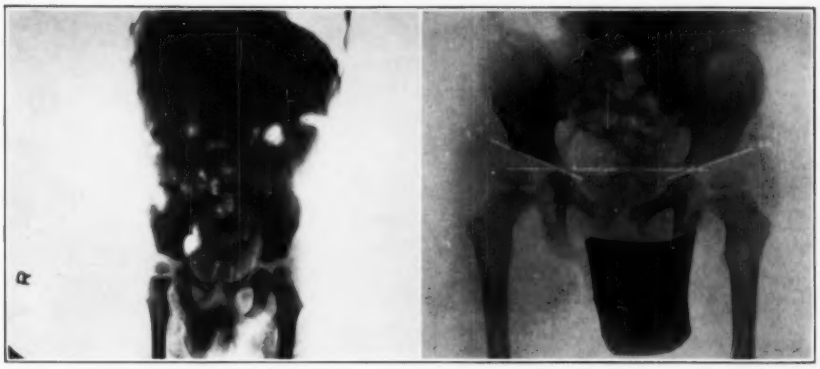


FIG. 1-A FIG. 1-B

Fig. 1-A: A.S. The roentgenogram of this severely spastic quadriplegic boy was made in 1955 when he was three years old. Treatment consisted in placing the child in a standing table for three hours a day.

Fig. 1-B: Roentgenogram made in 1958 when the patient was six years old. Note the definite increase in the angle of the femoral neck.

but also delayed weight-bearing and hence lack of the normal forces on the femoral neck incidental to assuming the erect position. According to Wolff's law, some abnormalities in the formation of the femoral neck and acetabulum might be anticipated.

Acquired Dislocation of the Hip Due to Coxa Valga

Congenital coxa valga, a well recognized entity, was described by Drehmann in 1906, Preiser in 1908, and Springer in 1909. Hass quoted Preiser as considering it one of the factors, in common with increased acetabular obliquity and anteversion of the femoral neck, which may lead to congenital dislocation of the hip. Putti, on the contrary, considered it of no significance. It is difficult to determine coxa valga by roentgenograms in infants, although the incidence is high at this age, because of the cartilaginous nature of the neck and head. On the other hand, dysplasia or increased acetabular obliquity can be seen readily even in one-day-old infants and are known to be no more common in children with cerebral palsy than in normal children. Persistence of normal coxa valga of infancy due to the absence of weight-bearing was observed by Whitman who stated that it was sometimes seen in limbs which never supported weight. This was also described by Jones and Lovett as occurring in a young child with poliomyelitis. They remarked that this deformity might be seen only in the affected leg which bore no weight. In the unaffected leg, however, one would find a normal angle of the neck and shaft of the femur.

In cerebral palsy, therefore, one may assume that the coxa valga observed in these children is related to delayed weight-bearing. The incidence of coxa valga in 100 children with cerebral palsy who had not borne weight until the age of four years was compared with 100 normal and cerebral palsied children who had borne weight. Persistent coxa valga was observed in about 25 per cent of those who had not borne weight while in the weight-bearing group the incidence was between 3 and 4 per cent. Roentgenograms of the hips and pelves, obtained for various reasons, were used in making these measurements. The exact position of the hips when the roentgenogram was made was not known, making accurate measurement of the neck-shaft angle difficult. Measurements were made with a protractor and the only films used were those in which the hip appeared to be in neutral position since the tip of the lesser trochanter was just visible on the medial side, and the epiphysis of the greater trochanter was plainly visible on the lateral side. All patients in whom the angle formed by the femoral neck and

FIG. 2

FIG. 3

Fig. 2: Case 1. N.M. This girl had never borne weight. Roentgenogram shows bilateral marked coxa valga and bilateral dislocation. There are no abnormal muscle pulls, only a completely inefficient vertical mechanical pull of the glutaeus medius.

Fig. 3: Case 2. B.H. This sixteen-year-old girl with bilateral coxa valga had not borne weight until she was ten. Spastic paraplegia is more marked on the left, where subluxation is also apparent.

shaft exceeded 150 degrees were arbitrarily considered as showing persistent coxa valga.

In coxa valga, the position of the greater trochanter is almost directly below instead of lateral to the origin of the glutaeus medius. As a result, the force of contraction of this muscle is directed vertically, rather than diagonally downward and outward, or nearly horizontally as with normal angulation of the neck. Normally, contraction of the glutaeus medius causes abduction of the hip. When the pull of this muscle is nearly vertical, however, its effective force as an abductor is decreased or completely eliminated with a consequent loss of lateral balance, a swaying gait, and a pseudo-Trendelenberg sign. The consequent imbalance between abductor and adductor power may result in adduction contracture and scissors gait. Thus, it can be seen that the scissors gait, so often seen in cerebral palsy, is not always necessarily due to spasticity of the adductors in patients with coxa valga. In these instances, the muscle imbalance producing scissors gait may result from inefficiency of the abductors of the hip caused by coxa valga. Regardless of the cause of the imbalance, the femoral head may be rocked out of the acetabulum with subsequent lateral and posterior dislocation. Where coxa valga is the predominant cause of dislocation, the prevention of such dislocation would seem to depend on correcting the valgus deformity in order to improve the mechanical advantage of the glutaeus medius. Where coxa valga is due to lack of glutaeus medius function, adduction tenotomy is not indicated. In our experience, very early weight-bearing, begun when the bone age is nine to ten months, using supportive leg splints and a standing table, has produced a decrease in the angle of the neck when weight-bearing is continued over a period of two years. The amount of standing time has been arbitrarily set at three hours a day, but for not more than one hour at a time (Figs. 1-A and 1-B).

In five patients so treated who were followed by me for from four to six years, there has been an average decrease of the femoral-shaft angle of 30 degrees (from 175 to 145 degrees). In many other patients I observed who have not been so treated, the angle has remained at about 175 degrees. In none of the patients treated by early weight-bearing has subluxation of the hip occurred, while a

FIG. 4

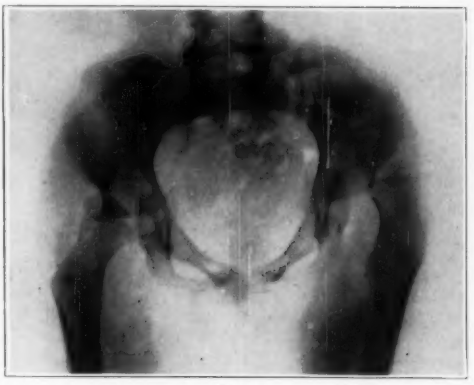


FIG. 5

Fig. 4: Case 3. C.Z. This eight-year-old girl with atonic diplegia had never borne weight and had no abnormal pull of adductors or gracilis. This roentgenogram, made three years after a shelf operation (performed elsewhere), shows that the shelf had been completely absorbed.

Fig. 5: Case 4. K.P. This boy, eight years old, had rigidity rather than true spasticity and had never walked. The tight, rigid, cordlike adductors created abnormal muscle pull which resulted in dislocation. The acetabular cavity is not changed in shape as it is in gracilis dislocation.

substantial number of dislocations have been observed in children not so treated. In none of the dislocations associated with coxa valga has there been any change in the acetabular roof, and the acetabular angle has been normal.

Although subtrochanteric osteotomy of the femur is a method of reducing the angle formed by the neck and shaft of the femur, I have had no experience with this procedure in young children with cerebral palsy. In older children, on the other hand, osteotomy to reduce valgus deformity has been found to result in a stable hip, even in the presence of incipient subluxation. If osteotomy is performed, both coxa valga and anteversion or femoral torsion should be corrected simultaneously.

Although anteversion or femoral torsion unquestionably plays a part in the production of dislocation of the hip in cerebral palsy, I have found that femoral torsion is a late development in this condition, seeming to result from prolonged sitting on the floor with the hips and knees in acute flexion and the feet backward. This position is assumed by the child who is unable to stand because it provides a wide base of support. It places both femora in full internal rotation and if this position is assumed habitually for two to three years it may result in marked internal femoral torsion or anteversion. The internal rotation of the hips which so frequently characterizes the gait of adults with cerebral palsy would appear to be the result, in some measure, from this persistent internal torsion. Although femoral torsion produces an ungainly gait, it does not seem to be so important a factor in the production of acquired dislocation of the hip as coxa valga.

In the author's experience, if weight-bearing is started early and sitting is largely eliminated, femoral torsion does not develop.

CASE 1. N.M., a girl, six years old, had severe ataxia. She had never borne weight on the lower extremities. Roentgenograms made when the child was six showed bilateral dislocation of the hips with marked coxa valga (Fig. 2).

In this instance, there was no spasticity or contracture but merely ataxia. Due to marked coxa valga, the pull of the abductor muscles was rendered completely ineffective. The resultant imbalance between these and the adductors produced dislocation of both hips.

CASE 2. B.H. This girl, sixteen years old, had spastic paraplegia, more marked on

FIG. 6

FIG. 7-A

Fig. 6: Case 5. C.B. Roentgenogram of the hips of this ten-year-old boy with spastic quadriplegia shows the acetabular roof to be well preserved with no coxa valga. The patient wore braces and used the standing table since early childhood.

Fig. 7-A: Case 6. B.W. Roentgenogram made when this child with cerebral palsy and left spastic hemiplegia was seven years old was interpreted as showing a normal hip, although there is possibly a slightly increased slant of the acetabular roof on the left.

FIG. 7-B

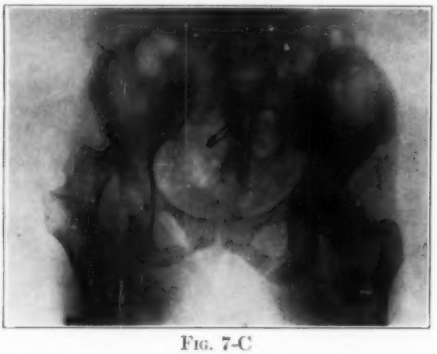


FIG. 7-C

Fig. 7-B: Roentgenogram made when the patient was thirteen showed the acetabular roof to be badly eroded on the left side.

Fig. 7-C: At the age of fifteen there is no evidence of the acetabulum on the left.

the left. She did not begin to stand until she was ten. At the time of writing, six years later, there is no adductor spasticity and the knees are straight. Roentgenograms (Fig. 3) showed bilateral coxa valga and subluxation of the left hip, the result, presumably, of coxa valga and related inefficiency of the glutaeus medius.

CASE 3. C.Z. A girl, eight years old, had atonic diplegia and had never borne weight on her lower extremities. There was no spasticity or contracture of either the adductor or gracilis muscles. A shelf operation on the right hip to prevent further subluxation had been performed on the child elsewhere when she was five years old. Three years later this shelf had been completely absorbed (Fig. 4), and a similar procedure recently done on the left side may also be absorbed.

Acquired Dislocation Due to Abnormal Muscle Pulls

Adductor type of dislocation: Dislocation of the hip due primarily to spasticity of the adductor muscles in patients with cerebral palsy presents a different picture. Here the angle of the femoral neck is normal or nearly normal but there is marked scissors gait. The abductors have a normal mechanical advantage but they are overpowered by the high degree of adductor spasticity involving the

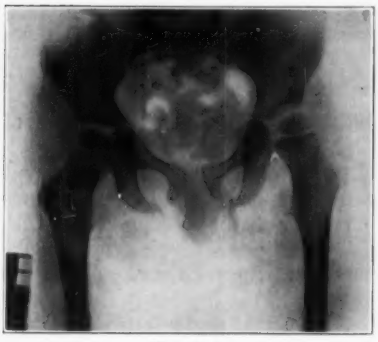


FIG. 8-A

FIG. 8-B

Fig. 8-A: Case 7. T.B. Roentgenogram made when this boy with cerebral palsy and left spastic hemiplegia was ten years old. There is a tight gracilis on the left, an adequate acetabular roof, and some coxa valga bilaterally.

Fig. 8-B: Roentgenogram made three years later shows the acetabulum to be enlarged with erosion of the roof.

pectineus, adductor longus and brevis, and occasionally the adductor magnus. When dislocation of the hip occurs here, the femoral head is rocked out of the acetabulum. There is no change in the size or shape of the acetabulum and the dislocation is lateral or often posterior without upward displacement.

In these cases early adductor tenotomy will prevent the development of dislocation. I have found that dislocation rarely follows adductor tenotomy when the angle formed by the neck and shaft of the femur is normal. However, a number of hips have dislocated after adductor tenotomy when coxa valga was present. Contractures of the adductors will re-form under these circumstances and dislocation of the hip may supervene.

CASE 4. K.P. This eight-year-old boy had rigidity rather than true spasticity and had never walked. His hips had been held habitually in the adducted position because of overpull of the adductors. Dislocation of both hips had occurred when the child was four with subsequent development of pain. Roentgenograms made when the child was eight showed moderate coxa valga and well preserved acetabular roofs (Fig. 5). Pain was relieved by adductor tenotomy. In this patient dislocation would appear to be the result primarily of excessive muscle pull in the adductor group.

CASE 5. C.B., a boy, ten years old, with spastic quadriplegia had never been able to walk or stand without support. Dislocation of the hip occurred on the right when the child was three and on the left when he was five. Roentgenograms made when the boy was ten showed the acetabular roof of each hip to be well preserved with no coxa valga (Fig. 6). Pain in both hips was relieved by adductor tenotomy.

Gracilis type of dislocation: A less common dislocation of the hip due to abnormal muscle pull is related to either spasticity or contracture of the gracilis muscle or to a combination of both spasticity and contracture.

The gracilis is the only muscle which is both a knee flexor and an adductor of the hip. The other hamstrings—biceps femoris, semimembranosus, and semitendinosus—arise from the ischial tuberosity. The force exerted by these muscles is essentially vertical, while the gracilis, which arises from the symphysis pubis, exerts a diagonal force upward and medially. In the presence of a tight gracilis, adduction of the hip takes place when the knee is passively extended. The test for a tight gracilis is to place the patient face down on the table with the knees flexed to 90 degrees. The legs are then abducted as far as possible, and the knees gradually extended. If the gracilis is not tight or spastic, there will be no tendency for the hips to adduct as the knees are extended. When the gracilis is tight, there is, of course, some degree of knee flexion contracture, which, if forced

FIG. 9

Fig. 9: Case 8. G.Z. This twelve-year-old boy had partial erosion of the right acetabulum. Roentgenogram made eight years after gracilis procedure shows that the degree of acetabular erosion has remained unchanged.

out into extension, results in adduction of the hip.

I first suspected this gracilis syndrome in 1936 when trying to correct knee flexion deformities by wedging casts with the legs held in abduction by an abductor bar. Hip pain and subsequent subluxation of the hip resulted from this procedure in two patients treated early in my experience. In later patients with this syndrome, section of the gracilis was found to eliminate this difficulty. Myotomy was carried out in the middle of the belly of the muscle to eliminate both its adductor and its knee-flexor function.

Gradual dislocation of the hip has been observed in ten patients. In all, varying degrees of erosion of the acetabular roof occurred concomitantly with progression of the dislocation, yet there was no evidence of tuberculosis or any other disease process in the involved hip joint. There was also no history of injury.

CASE 6. B.W. A girl with cerebral palsy and left spastic hemiplegia received no treatment. She was seen only at rare intervals by the author. The patient is able to walk independently. The gracilis test is positive. A roentgenogram made when the girl was seven was interpreted as showing a normal hip although, in retrospect, it would appear that there is slight upward inclination of the acetabular roof on the left (Fig. 7-A). In roentgenograms made when the patient was thirteen the acetabular roof was found to be badly eroded on the left side (Fig. 7-B). Two years later, roentgenograms (Fig. 7-C) disclosed no evidence of the acetabulum on the left. At that time the patient had a severe but painless limp.

CASE 7. T.B., a boy with cerebral palsy and left spastic hemiplegia was first seen when he was ten years old. At that time a tight gracilis was noted on the left and roentgenograms revealed an adequate acetabular roof and some coxa valga bilaterally, more marked on the left. This was difficult to evaluate because of the externally rotated position of the hips, when the roentgenograms were made (Fig. 8-A). The diameter of the left femur was less than that of the right. Roentgenograms made three years later showed that the acetabulum had enlarged with erosion of the roof (Fig. 8-B). Section of the gracilis was performed at that time and no further erosion of the acetabulum has taken place. The patient walks with a limp but has no pain; he was last examined five years after gracilis myotomy.

The author now has a series of five patients who were first seen at the ages of four, four, six, seven, and five, respectively. Initial examination revealed tight gracilis muscles and roentgenograms showed slight acetabular erosion. Gracilis section was performed. In the five years or more that all patients have been followed no further erosion or enlargement of the acetabulum has taken place.

CASE 8. G.Z. A boy with partial erosion of the right acetabulum had gracilis procedure performed on him when he was four years old. Roentgenograms (Fig. 9) made eight years after operation showed that the degree of acetabular erosion has remained unchanged.

SUMMARY

Acquired dislocation of the hip in cerebral palsy appears to result from: (1) coxa valga, due to late weight-bearing; (2) spasticity or contracture of the adductor muscles; or (3) spasticity or contracture of the gracilis muscle. These three types are distinguishable from congenital dislocation of the hip and from each other on the basis of roentgenographic and clinical findings. Prevention of each type of dislocation is often possible by the specific measures described.

REFERENCES

1. DREHMANN, GUSTAV: Beitrag zur Lehre der Coxa Valga. Zeitschr. Orthop. Chir., 17: 429-441, 1906.

2. Gherlinzoni, Giorgio, and Pais, Carlo: Trattamento della lussazioni patologica dell'anca. Indicazioni, tecnica e resultati lontani. Chir. Org. Movimento, **34:** 335-427, 1950.
3. Hass, Julius: Congenital Dislocation of the Hip. Springfield, Illinois, Charles C. Thomas, 1951.
4. Jones, Robert, and Lovett, R. W.: Orthopedic Surgery. Ed. 2. New York, William Wood and Co., 1929.
5. Mathews, S. C.; Jones, M. H.; and Sperling, S. C.: Hip Derangements in Cerebral Palsied Children. *In* Proceedings of the Annual Meeting of the American Academy of Cerebral Palsy, pp. 22-30. Baltimore, The Williams and Wilkins Co., 1953.
6. Preiser, Georg: Die Coxa Valga congenita—die Vorstufe der Kongenitalen Hüftverrenkung. Zeitschr. Orthop. Chir., **21:** 177-196, 1908.
7. Springer, K.: Ein Fall von Coxa Valga. Münchener Med. Wochenschr., **56:** 1909.
8. Tachdjian, M. O., and Minear, W. L.: Hip Dislocation in Cerebral Palsy. J. Bone and Joint Surg., **38-A:** 1358-1364, Dec. 1956.
9. Whitman, Royal: A Treatise on Orthopaedic Surgery. Ed. 6. Philadelphia, Lea and Febiger, 1919.

DISCUSSION

Dr. William Cooper, New York, N. Y.: The series of events which culminate in dislocation of the hip in cerebral palsy is an interesting practical demonstration of abnormal biomechanics. I would interpret the three types of dislocation which Dr. Phelps presented as three stages in the same mechanism. Coxa valga is certainly the first of the circumstances which predispose to dislocation. Failure to develop weight-bearing produces coxa valga or preserves it. To this may be added the strong pull of spastic adductors on the femoral shaft, tending to straighten the angle of the neck. In the next stage, strong adductor and flexor spasm maneuvers the femoral head into an unstable position. Finally, all the strong axial muscles of the femur which originate in the pelvis, especially the adductors, but also the hamstrings, pull together to displace upward the already unstable femoral head. The grac-

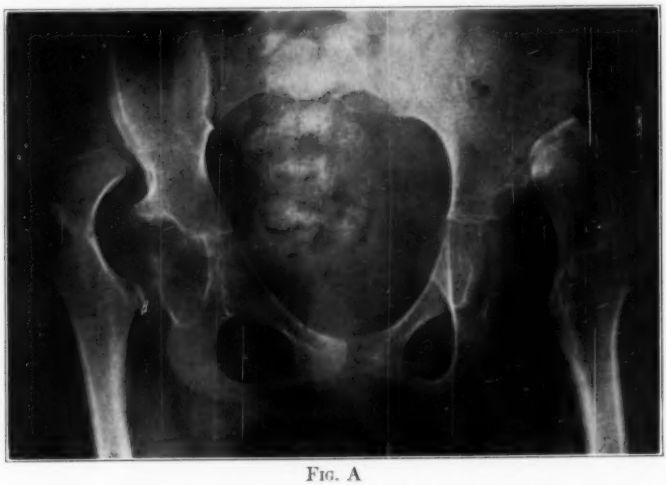


Fig. A

The findings typical of dislocation of the hip in cerebral palsy are flattening of the femoral head from soft-tissue pressure often associated with pain.

ilis muscle surely contributes to this mechanism, but to consider it the sole cause seems too much like picking on the youngest and weakest member of a family.

I agree with Dr. Phelps that we should prevent dislocation if we can. This would involve applying the reverse of the factors which produce the dislocation: weight-bearing instead of non-weight-bearing, and most important, relief of continuous and strong adduction in the hips. Braces may control adduction in the milder cases. Ordinarily, if the process of dislocation is already started, release of adduction is in order. Adductor tenotomy, including the gracilis, and one or both branches of the obturator nerve is carried out. I must say that I do not have Dr. Phelps' reluctance to do intra-abdominal obturator neurectomies and often rely on this procedure to provide relief of adductor spasm. I have never seen the persistent contracture of the abductor muscles he refers to following this operation.

The real problem of dislocation, however, is pain. This, to me, overshadows every other consideration. I am neither startled nor particularly distressed by the dislocation it-

self. These are ordinarily seriously disabled children and the mere fact of dislocation does not usually modify their physical competence very much. On the other hand, significant pain demands attention. It is not always present, but it does occur frequently and may be severe.

It is my opinion that pain is primarily the result of pressure of the dislocated head of the femur on the abductor muscles (Fig. A). For the pain which may develop, Dr. Phelps advises adductor release if considerable spasm is present. I have found it much more comforting to the patient to release the abductor muscles overlying the femoral head, stripping them from the ilium until the capsule is fully exposed. One may, in addition, release the adductors and hamstrings if they are contracted in order to further reduce upward tension. The results of this procedure have been very helpful in relieving symptoms.

Dr. Lenox D. Baker, Durham, North Carolina: Dr. Phelps mentioned that he does not see a combination of the various acquired dislocations of the hip in the cerebral palsied patient. It is my opinion that the three changes do occur together. I have seen them on roentgenograms of two patients. The acetabulum showed the effect of the gracilis pull and as a result of adductor pull the femur was in extreme adduction and was seen to be riding partially out of the acetabulum. There was valgus deformity of the neck of the femur. If these changes are corrected and controlled unilaterally in the paraplegic or the quadriplegic patient, during convalescence and thereafter, the opposite extremity should be closely observed since the more severely adducted femur may have held the opposite hip in abduction. With correction of the more severely involved hip, the opposite hip can then go into adduction and dislocation may occur.

The adduction dislocation is not likely to occur when the two sides are equally involved, but the gracilis dislocation can. When hip dislocation, regardless of etiology, is not prevented, pelvic obliquity and disabling scoliosis develop. This combination leads to severe disability that is equally disabling to the ambulatory and to the wheel-chair patient.

Dr. Phelps (closing): In Dr. Cooper's discussion about the adductor or gracilis, I think that the procedures which have been carried out in the patients with severe cases are perfectly all right. What I am looking for is the patient with a relatively mild case who has a normal looking roentgenogram and then later a dislocated hip. This is the one, I think, on whom you don't want to do extensive surgery. You want to find out what factor is causing this, and prevent the dislocation. All other procedures are useful when there is severe spasticity.

I feel certain that anteversion must be studied very carefully in each patient and appropriate surgical measures taken.

Chronic Neurological Sequelae of Acute Trauma to the Spine and Spinal Cord

Part II

The Syndrome of Chronic Anterior Spinal Cord Injury or Compression. Herniated Intervertebral Discs

BY RICHARD C. SCHNEIDER, M.D., ANN ARBOR, MICHIGAN

From the Sections of Neurological Surgery, Departments of Surgery, University of Michigan Hospital and Medical School; St. Joseph Mercy Hospital, Ann Arbor, Michigan; St. Vincent Charity Hospital, Cleveland, Ohio; and the United States Veterans Administration Hospital, Parma, Ohio

Patients with acute or chronic recurrent traumatic lesions of the spine and spinal cord may recover initially, but neurological sequelae may develop years later. At that time a diagnosis of degenerative disease, neoplasm, inflammatory condition of the central nervous system, or spinal-cord compression due to hypertrophic arthritis may be made erroneously. There is little realization that the chronic disability may stem from recurrent injuries to the cervical spinal cord or from a long since forgotten single traumatic episode. Efforts should therefore be directed toward obtaining a complete history and initiating early definitive therapy in acute spine injuries in order to avoid these unfortunate results.

Part I was presented in an earlier publication [12]. This dealt exclusively with the acute flexion or "tear-drop" fracture-dislocation of the cervical spine, a lesion which is particularly apt to cause chronic difficulty. Stress was placed upon the fact that the early proper realignment of the fracture-dislocation and satisfactory spine fusion might prevent delayed neurological signs and symptoms [6,7,8,12].

This portion, Part II, will be devoted to the problems associated with the chronic sequelae of herniated intervertebral discs which have caused the pattern of chronic anterior cervical spinal-cord injury or compression. This syndrome is characterized by gradually progressive weakness and spasticity with hyperreflexia in the lower extremities and extensor plantar reflexes without significant sensory change initially. Eventually, in some cases these motor changes may be associated with the development of a dermatome level of hypalgesia and hypaesthesia [1,2,3,4,5,9,10,12,13,14]. The mechanism of this neurological pattern is discussed in Part I and will not be reviewed here.

The realization that spinal-cord compression may cause recurrent trauma to the cord as the result of the stresses and strains of everyday movement of the spine seems to be entirely foreign to medical thinking. Nevertheless, this concept as a form of chronic spinal-cord injury must be fostered if accurate diagnosis and treatment are to be attained.

The follow-up study of patients with this type of lesion is becoming an increasingly difficult problem. Our population has become more mobile in recent years with the result that frequently there is lack of continuity of care of the patient by one physician. The practice of microfilming roentgenograms and records in many hospitals in order to conserve filing space and the statute of limitations have led to the relatively early disposal of old roentgenograms. All too frequently it is impossible to borrow the original films for comparison with the current ones. In the following cases, which will serve as illustrations, some of these problems have been overcome by the close cooperation of neurosurgical and orthopaedic colleagues in other institutions, by the exchange of medical reports by mail, and

FIG. 1-A

FIG. 1-B

Fig. 1-A: Case 1. Lateral roentgenogram showing straightening of the normal lordotic curve of the cervical spine.

Fig. 1-B: Myelogram showing constant filling defect at fifth cervical-sixth cervical interspace indicating a space-taking lesion.

by travel on the part of the author to distant hospitals to examine microfilmed records and roentgenograms.

CASE 1. L. B., a hog slaughterer, forty-nine years old, was admitted to the United States Veterans Administration Hospital, Parma, Ohio, on March 24, 1949. Two weeks prior to admission constant discomfort in the neck and left shoulder developed; this was aggravated by any flexion of the neck. Associated with this pain he noted inability to raise the left arm and shoulder; intermittently he had a staggering gait. The cervical pain disappeared only to be replaced by pain radiating into the left elbow and wrist upon any shoulder movement. He had no bladder or bowel incontinence. There was no history of any direct forcible injury to his neck or head. For five years prior to the onset of symptoms his work, four days a week, had consisted in killing 700 hogs a day by striking them upon the head and neck with a club.

The patient had tenderness over the lower mid-cervical spine, but he displayed no limitation of motion of the head and neck. He had complete paralysis of the left deltoid muscle, as well as marked weakness of the internal and external rotator muscles of the shoulder and the supinator muscles of the left forearm. There was mild weakness and spasticity of both lower extremities. He had hypaesthesia in the left fifth cervical dermatome. His vibration sense was diminished in both feet but touch, motion, and position sense were all intact. The deep reflexes were symmetrically hyperactive with pathological pyramidal tract signs in all four extremities. His gait was normal and the Romberg test was negative. Upon lumbar puncture, a clear colorless cerebrospinal fluid was obtained with normal manometric studies. The total protein was 40 milligrams per 100 cubic centimeters. The Kahn test was negative and the colloidal gold curve was normal. Roentgenograms of the cervical spine showed no abnormality except straightening of the lordotic curve (Fig. 1-A).

A neurological consultant made a diagnosis of amyotrophic lateral sclerosis with pain secondary to shoulder-joint adhesions but advocated that myelography be considered to exclude an expanding cervical lesion. Several neurosurgical consultants felt that the patient probably did not have a surgical cervical lesion, but agreed to cervical myelography by the cisternal route. When this was performed, no evidence of subarachnoid block was noted; however, the pantopaque was not observed as it passed through the cervical spinal canal. Another neurological examination on May 19, 1949, showed essentially the same findings, but the patient now had

atrophy of the left deltoid, biceps, and brachialis. The left biceps reflex was markedly diminished and the superficial reflexes, both abdominal and cremasteric, were absent. Myelography was repeated by the lumbar route revealing a constant filling defect at the fifth cervical-sixth cervical interspace with the characteristics of a herniated nucleus pulposus at this level (Fig. 1-B).

Laminectomy of the fifth, sixth, and seventh cervical vertebrae was performed on May 31, 1949. The epidural fat was absent at the fifth cervical-sixth cervical interspace and the dura was firm and bulging posteriorly. The dura was incised in the mid-line and the arachnoid was opened laterally. The denticulate ligaments were cut at three segments to permit gentle retraction of the cord. The dura was opened anteriorly on the left side of the fifth cervical-sixth cervical interspace and a completely extruded fragment of the nucleus pulposus herniated through this incision in the dura. The interspace was cautiously curetted. Because of the swelling of the cord, the arachnoid was merely allowed to fall back into place and the dura was left open. The remainder of the wound was closed in the routine fashion. Postoperatively, the patient made an uneventful recovery with gradual return of strength in all the preoperatively paretic muscles.

CASE 2. G. F., a floor lady in a quilting factory, forty-eight years old, was admitted to the Neurological Service at University Hospital, Ann Arbor, Michigan, on August 4, 1955, complaining of right lower extremity numbness of four months' duration. She had been in good health until October 1954 when she had first noted progressive fatigue. In April 1955 she began to drag her legs in a shuffling gait. One day her "legs tightened and toes curled up", and she had to be helped to a chair suffering from a painless paralysis of both legs of ten minutes' duration. She was confined to her local hospital for the next ten days with a diagnosis of arthritis and hysteria. She finally improved to the extent that she could drag herself from one chair to another. One day she became incontinent of bladder and bowel simultaneously, stiffness developed in the right index and middle fingers, and numbness in her lower extremities. Further inquiry into her history disclosed that her last menstrual periods were in March 1954 and February 1955, and that since the latter date she had had a brownish vaginal discharge almost daily. There had also been a twenty-one-pound weight loss in the previous four months.

On physical examination the vital signs were normal. The only positive physical findings were an impression of a fixed, deep pelvic mass and a liver palpable three centimeters below the costal margin.

The positive neurological findings were a stiffness on flexion of the right index and middle fingers with atrophy of the interosseus muscles and moderate paresis in flexion of both knees and hips and in adduction of both hips. Fasciculations were observed in the deltoid muscle bilaterally and in the left anterior thigh muscles. Although vibration and position sense were intact there was a level of hypalgesia below the second thoracic dermatome on the right and the fifth thoracic dermatome on the left. She had bilateral hyperactive deep tendon reflexes, ankle and patellar clonus, together with upper and lower extremity pyramidal tract signs. A diagnosis of a spinal-cord tumor at the level of the sixth and seventh cervical segments was made.

Roentgenograms of the cervical spine showed slight hypertrophic spurring at the fifth cervical-sixth cervical and the sixth cervical-seventh cervical interspaces. Cervical myelography demonstrated a central lesion extending between the fourth and seventh cervical levels with an almost complete blockage of the subarachnoid space (Fig. 2-A). In the lumbar area there were defects at the third lumbar-fourth lumbar and fourth lumbar-fifth lumbar interspaces (Fig. 2-B). The cerebrospinal fluid removed at the time of myelography had a total protein content of 35 milligrams per 100 cubic centimeters.

On August 9, 1955, the patient had a complete laminectomy of the fifth, sixth, and seventh cervical vertebrae. The dura was opened in the mid-line, three pairs of denticulate ligaments were sectioned, and a mid-line mass protruding slightly to the right could be palpated at the sixth cervical-seventh cervical interspace. On transdural exploration a markedly degenerated extruded intervertebral disc was removed bilaterally from this interspace and the wound closed in layers. No evidence of any tumor was found.

Upon close questioning of the patient postoperatively, it was discovered that she had been employed in a quilting factory for about ten years and had been unloading machines sporadically. This work consisted in permitting thirty to eighty pound bolts of cloth to drop on either shoulder. For the two years prior to her admission to the hospital this had been a continual process with approximately forty-eight such unloading episodes daily.

A postoperative wound infection developed which extended to the level of the dura. This was drained and she improved; but later there was a recurrence of infection and tetraparesis developed. She was discharged in this condition in December 1955 and has had only partial recovery of strength in her extremities since that time.

CASE 3. P. C., a man, forty-one years old, was bowling one evening in 1947 when he observed that he was catching cold. Every time he coughed or sneezed he sustained a sharp radiating pain down the posterior aspect of both thighs and legs. On the following day he noted numbness along the lateral aspects of the leg and foot bilaterally. This bothered him sufficiently so that he saw a

FIG. 2-A

FIG. 2-B

Fig. 2-A: Case 2. Central myelographic defect is noted at the fourth cervical through the seventh cervical levels with an almost complete blockage of the subarachnoid space.

Fig. 2-B: Mutiple defects were also noted in the myelogram at the third lumbar-fourth lumbar and fourth lumbar-fifth lumbar interspaces.

neurosurgeon who made a lumbar myelogram. It was normal and a diagnosis of acute myelitis was made. The patient sought consultation of a second neurosurgeon who re-examined him. He made another lumbar myelogram which was also normal and confirmed the diagnosis of myelitis. In January 1948, the second neurosurgeon performed a cisternal myelogram in the upright position, which was reported to show a cupping at the fifth cervical-sixth cervical interspace. Operation was apparently considered, but finally was rejected by the neurosurgeon. The patient stated that immediately after the last myelogram bladder and bowel impairment developed which endured for a long interval.

In March 1949, he was seen by the author in another city. By this time he had a more severe neurological deficit. He now felt numbness to the mid-chest level but there was no pain. His gait had become more spastic and unsteady. Percussion over the entire spine caused no tenderness or radiating discomfort. He had weakness only in the interosseus muscles of the left hand. Evaluation of the strength in the lower extremities was difficult because of his marked spasticity and clonus. Fasciculations were noted in the left thenar space. There was hypaesthesia up to the left seventh cervical dermatome and to the right fourth thoracic dermatome. Touch was spottily preserved on the inner aspect of both legs and thighs, but vibration sense was retained. He had bilateral extensor plantar reflexes and a positive Romberg test. A herniated nucleus pulposus was postulated but the patient denied a history of any cervical trauma.

The patient was admitted to St. Vincent Charity Hospital, Cleveland, Ohio, in March

1949. A lumbar puncture revealed a clear, colorless cerebrospinal fluid with a partial block of the subarachnoid space on jugular compression. The spinal-fluid protein at the time was 45 milligrams per 100 cubic centimeters. A cervical myelogram following the instillation of pantopaque by lumbar puncture demonstrated a pronounced spindle-shaped defect at the fifth cervical-sixth cervical and the sixth cervical-seventh cervical interspaces (Fig. 3). The patient was repeatedly questioned about trauma and finally, after much thought, recalled that in 1938, eleven years before this hospital admission, he had been lifting a car bumper over another bumper in a parking lot when he suddenly felt an excruciating pain in the cervical region which radiated down his back and into both thighs and legs. He remained frozen in one position for five minutes and almost fainted. He had only minimal discomfort in his neck during the next few days and had completely forgotten this incident in the interim.

On March 9, 1949, he had a laminectomy of the fourth, fifth, sixth, and seventh cervical vertebrae. No epidural fat was found in these regions; the dura was bound in firm scar tissue. Above and below this region was a 0.5 centimeter layer of epidural fat. The dura was incised in the mid-line and the arachnoid opened laterally. At the lower margin of the wound the denticulate ligaments at the sixth cervical-seventh cervical interspace were taut, and they were in close approximation to the nerve roots. Bulging posteriorly was a firm, non-movable mass displacing the cord backward. Incision of the dura anteriorly exposed a firm, mid-line, protruded calcified intervertebral disc. Because of its fixed condition, no attempt was made to remove the lesion, but the cord was decompressed by cutting the denticulate ligaments at three interspaces. The dura was left open and the arachnoid sealed off the dural incision in the mid-line. The wound was then closed in layers.

At the time of discharge from the hospital on March 27, 1949, there was a level of spotty hypaesthesia from the seventh thoracic to the second lumbar dermatome on the left and from the twelfth thoracic to the second lumbar dermatome on the right. He had touch preserved throughout, but vibration sense was absent to the level of the clavicles. All movements of the right lower extremity were slightly weak. The spasticity in the lower extremities had diminished for now the patient was able to cross one leg over the other at the knee—a thing he had been unable to accomplish for two years. Patella and bilateral ankle clonus were elicited with bilateral extensor plantar reflexes. His gait was now improved, for he could now lift up one foot after the other while walking. Previously he had merely shuffled his feet in a spastic gait. His Romberg test, however, remained positive.

FIG. 3

Case 3. Myelogram showing a marked spindle-shaped defect at the fifth cervical-sixth cervical and sixth cervical-seventh cervical interspaces.

CASE 4. A. U., a woman, forty-one years old, was admitted to St. Joseph Mercy Hospital, Ann Arbor, Michigan, in January 1953, stating that she had had low-back pain for several years and that in September 1952, during an attack of virus pneumonia, pain radiating down the posterior aspect of the left thigh and lateral aspect of the leg to the dorsum of the foot developed. This pain gradually increased in severity until she had to remain in bed. The pain was increased by coughing, sneezing, and straining at defecation. There was weakness in dorsiflexion of the left foot. On bending forward at the waist there was definite local tenderness to percussion in the lower lumbar area without any radiating pain. The straight-leg-raising test could be performed to 45 degrees on the right and 30 degrees on the left. Dorsiflexion of the left foot caused marked sciatic pain. Dorsiflexion of the right foot caused radiation of pain into the left hip. She had hypalgesia over the left first lumbar dermatome. There was markedly increased deep reflexes bilaterally with a left extensor plantar reflex and bilateral pyramidal tract signs in her upper extremities. She had left ankle and patellar clonus. Because of the marked sciatica, a diagnosis was made of a possible herniated nucleus pulposus at the left of the fifth lumbar-first sacral interspace, but because of the extensor plantar reflex on the left side and the bilateral positive upper-extremity pyramidal tract signs, it was felt that the patient must have some lesion more cephalad, possibly in the cervical region. Repeated questioning evoked no previous history of cervical-spine trauma; therefore, cervical spinal-cord tumor, herniated disc, or hypertrophic

FIG. 4-A

FIG. 4-B

Fig. 4-A: Case 4. Myelogram showing filling defects at the fifth cervical-sixth cervical and sixth cervical-seventh cervical interspaces.

Fig. 4-B: The lumbar myelogram demonstrates a left fifth lumbar-first sacral defect.

vertebral spur had to be considered. A myelogram demonstrated a filling defect at the fifth cervical-sixth cervical and the sixth cervical-seventh cervical interspaces (Fig. 4-A). There was also a demonstrable lesion at the left fifth lumbar-first sacral interspace (Fig. 4-B). On January 30, 1953, a laminectomy was performed on the fourth and fifth lumbar and the first sacral vertebrae, and a protruded disc was removed bilaterally from the fourth lumbar-fifth lumbar interspace. The patient's postoperative course was uneventful with complete relief of the left sciatic pain and the weakness in dorsiflexion of the left foot.

Prior to operation the patient and her husband had been advised that she did have evidence of another lesion in the cervical region which had been confirmed by myelogram. The myelographic appearance was that of either multiple mid-line cervical protruded discs or hypertrophic spurs rather than tumor. It was suggested that it would be well to observe the patient before exploring this area.

The patient was readmitted to University Hospital on March 2, 1954, at which time she was complaining of pain in her left arm, the left side of her neck, and the left side of her head. She stated then that she had noted these pains for about four years prior to this admission but she had not mentioned them in her previous history in 1953. Her left sciatic pain had been so severe that she had forgotten about her neck. The symptoms referable to the left side of the neck and the left arm were accentuated by coughing and sneezing. She complained of severe occipital headache. Upon further questioning, the examiners found that the patient had sustained a fractured jaw in 1938 and had some neck pain at that time. On reviewing the 1938 hospital chart, it was discovered that the patient had been unconscious for a period of three days and, upon regaining her senses, had discomfort and tenderness to percussion over the fifth, sixth, and seventh cervical spinous processes.

On examination she had equivocal weakness of the left lower extremity. Hypalgesia was noted in the left forearm just above the wrist to the elbow on the ulnar aspect and at the end of the insertion of the deltoid muscle on the radial side. She also had decreased pain on the medial aspect of her left foot. There was a questionable Hoffmann reflex on the left and an

equivocal extensor plantar reflex on the right. Straight-leg raising was possible to 75 degrees on the left. She had tenderness over the lower cervical and upper thoracic spine.

On March 3, 1954, laminectomy of the fifth, sixth, and seventh cervical vertebrae was performed with decompression of the fifth, sixth, and seventh cervical-nerve roots. At the time of the operation it was felt that the left seventh cervical-nerve root was unusually stretched by the denticulate ligament and the latter was cut. The nerves making their exit through the left fourth cervical-fifth cervical and fifth cervical-sixth cervical foramina were bound in scar tissue and compressed by calcified intervertebral-disc fragments and bony exostoses. These nerve roots were released by chiseling away the bone. The patient tolerated the procedure well.

On follow-up examination three months later the patient was asymptomatic and well pleased with the result of the operation. She still had a Hoffmann's sign on the left with hyperactive left-sided deep reflexes. She was discharged to return to work.

DISCUSSION

Cases 1 and 2 illustrate how repeated stresses such as those incurred in the patient's everyday occupation may cause a complete extrusion of a cervical disc with many signs and symptoms of a degenerative or neoplastic lesion. The fact that several well trained men, neurologists and neurosurgeons, minimized the possibility of a surgical lesion, suggests the importance of presenting these cases. In Case 1 a diagnosis of amyotrophic lateral sclerosis was made, and in Case 2 the lesion was thought to be a spinal-cord tumor.

In Case 3 the onset of neurological symptoms and disability, pain and numbness in the lower extremities, resulted from a chronic cervical lesion with no symptoms directly referable to the involved area. As a result of two negative lumbar myelograms a diagnosis of acute myelitis was made by two certified neurological surgeons.

In Cases 1 and 3 both of the cervical lesions would have been confirmed much sooner, if the lumbar route of dye instillation had been used primarily rather than cisternal myelography employed with the patient in a sitting position. Earlier diagnosis might have prevented so marked a degree of neurological disability.

Cases 3 and 4 demonstrate that there may be such a long interval between the single traumatic incident and the occurrence of symptoms caused by the lesion that the injury may be completely forgotten.

In Cases 2 and 4 the fact is clearly emphasized that the patient who has an injured intervertebral disc in the cervical area may also have one elsewhere in the spine, possibly in the lumbar region or vice versa.

The value of procuring a comprehensive history and of performing a complete neurological examination on the patient with an acutely herniated lumbar disc is well illustrated in Case 4. The presence of pyramidal tract signs on the routine examination led to the discovery of a chronic herniated nucleus pulposus and associated hypertrophic spurs in addition to the extruded lumbar disc. Suspicion of such a lesion is important so that myelography may include the cervical as well as the lumbar area. If a cervical defect is encountered, both the patient and relatives may be advised that the patient may require not only a lumbar operation but also a cervical exploration at a later date. In this patient the changes in the cervical spine and intervertebral disc were located at the site of injury incurred sixteen years previously. Although the patient had forgotten the extent of the trauma, the 1938 hospital chart indicated that the cervical damage at that time was most likely the precursor of her later symptoms.

Conversely in Case 2 although a herniated cervical intervertebral disc was discovered, the definite lumbar myelographic defect suggested the possibility of protruded lumbar intervertebral discs. However, it is unlikely that this patient will have symptoms referable to the lumbar area in view of the severe degree of neurological deficit which resulted from the postoperative wound infection.

In all of the patients reported here chronic neurological signs secondary to intervertebral-disc protrusion have developed. As noted elsewhere [4], the denticulate ligaments prevent the spinal cord from being displaced posteriorly by the calcified protruded disc. As a result the disc lesion produces an area of direct stress

on the anterior portion of the cord, perhaps causing some loss of pain and temperature. However, there are also areas of stress just posterior to the attachments of the denticulate ligaments which account for the impairment of the lateral cortical spine tracts with the resulting spasticity, paresis, or paralysis. Motion, position, and vibration sense are preserved since there has been no compression of the posterior columns against the posterior bony portion of the canal. Painful symptoms were absent. A certain amount of clinical recovery may be secured merely by sectioning the denticulate ligaments in some of these patients, permitting the spinal cord to move freely in a posterior direction [3,4,5]. In more recent years, however, it has become my policy to employ a more radical type of operation which includes, if possible, not only sectioning of the denticulate ligaments but removal of the injured intervertebral disc and the hypertrophic cervical spur with the aid of fine oral surgery chisels and gouges. The results seem to indicate a better long-range prognosis for these patients.

SUMMARY

Four cases of ruptured cervical intervertebral discs are presented which, following a single traumatic episode or multiple recurrent injuries, showed symptoms and signs of the chronic anterior cervical spinal-cord injury or compression syndrome. These lesions were diagnosed as amyotrophic lateral sclerosis, spinal-cord tumor, acute myelitis, and spinal-cord compression due to hypertrophic arthritic spur. Earlier recognition and treatment would undoubtedly have prevented neurological disability.

REFERENCES

1. Bedford, P. D.; Bosanquet, F. D.; and Russell, W. R.: Degeneration of the Spinal Cord Associated with Cervical Spondylosis. Lancet, **2:** 55-59, 1952.
2. Brain, W. R.; Northfield, D.; and Wilkinson, M.: The Neurological Manifestations of Cervical Spondylosis. Brain, **75:** 187-225, 1952.
3. Bucy, P. C.; Heimburger, R. F.; and Oberhill, H. R.: Compression of the Cervical Spinal Cord by Herniated Intervertebral Discs. J. Neurosurg., **5:** 471-492, 1948.
4. Kahn, E. A.: The Role of the Dentate Ligaments in Spinal Cord Compression and the Syndrome of Lateral Sclerosis. J. Neurosurg., **4:** 191-199, 1947.
5. Mercer, Walter: Orthopedic Surgery. Ed. 4, p. 1016. Baltimore, The Williams and Wilkins Co., 1950.
6. Rogers, W. A.: Cord Injury During Reduction of Thoracic and Lumbar Vertebral-Body Fracture and Dislocation. J. Bone and Joint Surg., **20:** 689-695, July 1938.
7. Rogers, W. A.: Treatment of Fracture-Dislocation of the Cervical Spine. J. Bone and Joint Surg., **24:** 245-258, Apr. 1942.
8. Rogers, W. A.: Fractures and Dislocations of the Cervical Spine. J. Bone and Joint Surg., **39-A:** 341-376, Apr. 1957.
9. Schneider, R. C.: Acute Traumatic Posterior Dislocation of an Intervertebral Disc with Paralysis. J. Bone and Joint Surg., **31-A:** 566-570, July 1949.
10. Schneider, R. C.: A Syndrome in Acute Cervical Spine Injuries for which Early Operation is Indicated. J. Neurosurg., **8:** 360-367, 1951.
11. Schneider, R. C.: The Syndrome of Acute Anterior Spinal Cord Injury, J. Neurosurg., **12:** 95-122, 1955.
12. Schneider, R. C., and Kahn, E. A.: Chronic Neurological Sequelae of Acute Trauma to the Spine and Spinal Cord. Part I. The Significance of the Acute Flexion or "Tear-Drop" Fracture-Dislocation of the Cervical Spine. J. Bone and Joint Surg., **38-A:** 985-997, Oct. 1956.
13. Spillane, J. D., and Lloyd, G.H.T.: The Diagnosis of Lesions of the Spinal Cord in Association with "Osteoarthritic" Disease of the Cervical Spine. Brain, **75:** 177, 1952.
14. Stern, W. E., and Rand, R. W.: Spinal Cord Dysfunction from Cervical Intervertebral Disk Disease. Neurology, **4:** 883-893, 1954.
15. Symonds, C.: The Interrelation of Trauma and Cervical Spondylosis in Compression of the Cervical Cord. Lancet, **1:** 451-454, 1953.

Chronic Neurological Sequelae of Acute Trauma to the Spine and Spinal Cord

Part IV

Problems Pertaining to the Treatment of Retained Foreign Bodies

BY RICHARD C. SCHNEIDER, M.D., AND EDGAR A. KAHN, M.D., ANN ARBOR, MICHIGAN

From the Section of Neurosurgery, Department of Surgery, University of Michigan Medical School and Hospital, Ann Arbor

Before the advent of the sulfanilamides and antibiotics there was a tendency to treat penetrating wounds of the spine and spinal cord conservatively provided there was no leak of cerebrospinal fluid or evidence of indriven bone fragments. There was constant fear of spreading infection and the dangers of epidural abscess, meningitis, and death. Consequently some of the foreign bodies would lie *in situ* for many years before causing either the development of progressive neurological symptoms or possibly flare-up of an old, chronic inflammatory reaction. Two patients who were wounded by bullets and one who had received a stab wound years before seeking any medical care are presented as illustrations.

Key and Conwell maintained that removal of missiles was unnecessary since heat generated by the high velocity sterilized a bullet entering the body. This theory was well refuted in a report published by MacCarty and Mendelsohn. Their patient had been shot in the cervical region in 1901 and fifty years later, while cranking a car, felt a snap in his neck. A draining sinus had developed and the retained foreign body was discovered on roentgenographic examination. A foreign body may be present for years before its presence is manifested by signs and symptoms of infection. Since the antibiotics frequently are bacteriostatic rather than bacteriocidal, there is a chance that more of these patients with latent infections due to foreign bodies may be seen in the future. Although a metallic missile undoubtedly sterilizes itself it may introduce into the wound clothing and other material which are not sterile.

In 1950 Helfer reported two cases of prolonged spinal-cord compression of traumatic origin in which improvement of the patient's condition occurred following late surgical intervention. In one patient a 0.22 caliber bullet was recovered from the cervical region three and one-half years after injury with subsequent postoperative neurological improvement. Helfer stressed the fact that surgical intervention should be resorted to if diagnostic procedures showed a compression of the cord regardless of the interval elapsed from the time of injury.

CASE REPORTS

Retained Missiles

Case 1. F. B., an inmate of Southern Michigan Prison, fifty-six years old, sustained a gunshot wound of the upper thoracic region in 1918. He was immediately totally paralyzed below the level of the rib margins, but after an interval of several weeks he gradually made a complete recovery.

While working as a janitor on September 26, 1950, thirty-two years after having received his wound, the patient fell down a flight of stairs on his buttocks. Progressive weakness developed in the lower extremities but he had no incontinence of either bladder or bowel. Neurological examination twenty-four hours after the fall showed that although hypalgesia and hypaesthesia were elicited to the level of the right fifth thoracic dermatome there was no sensory impairment on the left. He had marked weakness, spasticity, hyperreflexia,

FIG. 1

FIG. 2-A

Fig. 1: Case 1. Anteroposterior-view roentgenogram of the thoracic spine made September 26, 1950, showing a retained foreign body, a bullet, with superimposed bone overgrowth at the space between the third and fourth thoracic vertebrae. There is impingement on the left side of the spinal canal.

Fig. 2-A: Case 2. Anteroposterior-view roentgenogram showing the retained bullet in the left side of the space between the third and fourth lumbar vertebrae.

FIG. 2-B

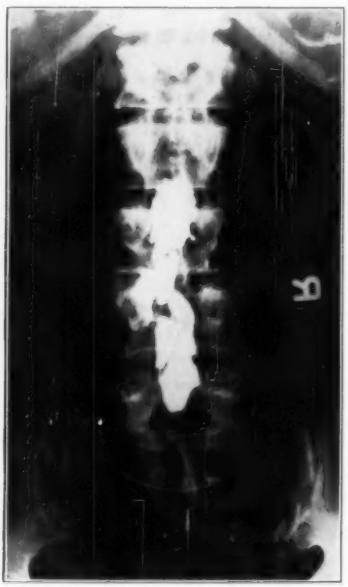


FIG. 2-C

Fig. 2-B: Lateral-view roentgenogram showing the bullet in the lamina at the space between the third and fourth lumbar vertebrae with superimposed bone overgrowth and impingement upon the spinal canal.

Fig. 2-C: Anteroposterior-view myelogram showing a filling defect at the level of the space between the third and fourth lumbar vertebrae (the site of the bullet) and suggesting arachnoiditis extending upward to the level of the second lumbar vertebra and downward through the space between the fourth and fifth lumbar vertebrae.

and clonus in the left lower extremity, minimal weakness in all muscles of the right lower extremity, and bilateral extensor plantar reflexes.

Roentgenograms of the thoracic spine revealed a retained foreign body just to the left of the third to fourth intervertebral space. The bullet was encapsulated in an osseous coating and protruded into the spinal canal (Fig. 1). Two months following the fall the patient observed improvement in strength and control of the extremities. He had a level of hypalgesia and hypaesthesia to the right seventh thoracic dermatome. Weakness in the left lower extremity remained unchanged and there was a left extensor plantar reflex. Lumbar puncture disclosed a clear, colorless cerebrospinal fluid with no evidence, on manometric testing, of a subarachnoid block. The total protein of this fluid was thirty milligrams per 100 cubic centimeters. The patient refused operation for removal of the foreign body.

On January 3, 1951, he was discharged from the hospital to his cell block where he was placed on limited duty prison routine until his release, January 29, 1954, and was then lost to follow-up.

CASE 2. W. B., a Southern Michigan Prison inmate, fifty-five years old, was shot in the right upper quadrant of his abdomen in 1944. Immediate, complete paralysis of his trunk and both lower extremities developed with a sensory deficit to the level of the waist. After two or three weeks he began to feel severe pain in both feet but gradually regained sufficient strength in both lower extremities for walking.

Nine years later, in August 1953, following a fall on his buttocks, the patient began complaining of sharp pain which radiated down the lateral border of the right thigh, the calf, and into the great toe. His discomfort was increased when straining at defecation and by urination. He had never suffered from any severe pain in the left leg. However, he had marked weakness in both dorsiflexion and plantar flexion of his left foot and complete paralysis of the extensor hallucis longus with toe-drop, a symptom which had become progressively worse. Atrophy was observed in the muscles of the left calf, thigh, and buttock. He exhibited hypaesthesia and hypalgesia in the left fourth lumbar dermatome and right fifth lumbar and first, second, third and fourth sacral dermatomes. Roentgenographic examination of the lumbar spine revealed a retained foreign body at the third to fourth intervertebral space on the left side (Fig. 2-A). A lateral view roentgenogram disclosed the retained foreign body, completely surrounded by bone, in the overlying lamina of the third to fourth (lumbar) intervertebral space at the posterior margin of the spinal canal (Fig. 2-B). A lumbar puncture was performed but there was no evidence of subarachnoid-space block. The cerebrospinal fluid total protein was seventy milligrams per 100 cubic centimeters. A myelogram showed an irregular filling defect at the space between the third and fourth lumbar vertebrae—the site of the bullet—suggesting arachnoiditis extending upward to the level of the second lumbar vertebra and downward to the level of the fourth lumbar vertebra (Fig. 2-C).

On August 24, 1954, the patient underwent complete laminectomy of the second, third, fourth, and fifth lumbar vertebrae. At the level of the third lumbar vertebra the foreign body was found imbedded in the hyperostotic third lumbar lamina. The left side of the cauda equina was severely compressed. When excising the bone fragments, pronounced encroachment was noted anteriorly on the left of the spinal canal. The scar was dissected from the dura mater and nerve roots. The lumbar-nerve roots were completely decompressed at the spaces between the third and fourth lumbar, fourth and fifth lumbar, and fifth lumbar to first sacral vertebrae bilaterally. A bilateral extradural exploration of the lumbosacral-joint space revealed no herniated nucleus pulposus. Upon opening the dura mater in the midline, a marked arachnoiditis was encountered which almost completely obliterated the subarachnoid space. The marked scarring posteriorly at the level of the spaces between the third and fourth and fourth and fifth lumbar vertebrae could have accounted for the apparent anterior compression of the cauda equina seen in the lateral view myelogram. In attempting to open the dura mater and separate the markedly scarred nerve roots intradurally, it was soon apparent that there was serious danger of interrupting motor fibers. Further dissection of these structures was deemed inadvisable, and the wound was closed in layers. After removal of the bullet at the space between the fourth and fifth lumbar vertebrae the nerve roots at this site and adjacent levels seemed to be well decompressed.

The patient was last seen by an orthopaedic surgeon on July 9, 1955, at which time it was revealed that he had residual muscle weakness in his left leg and was unable to push off with his left foot. This leads us to believe that he had residual left foot-drop. The pain in the right leg had been completely relieved.

The prisoner disappeared shortly after clearing parole on March 21, 1958.

In both patients (Cases 1 and 2) bullets had initially caused a marked neurological deficit which partially subsided after a brief interval. However, after a period of years another injury caused a recrudescense of the neurological symptoms and signs.

In Case 1, the patient was fortunate to have survived the gunshot wound in

FIG. 3-A

FIG. 3-B

Fig. 3-A: Case 3. Anteroposterior-view roentgenogram showing the remnant of knife blade (arrow) at the fourth thoracic vertebra lying almost in the center of the spinal canal.

Fig. 3-B: Lateral-view roentgenogram (retouched) exhibiting the length of the blade. (Reprinted by permission from "Asymptomatic Transfixion of Spinal Cord by a Knife Blade. Report of a Case." By Rafael Castillo and E. A. Kahn. J. Neurosurg., 7: 179-182, 1950. Springfield, Illinois, Charles C. Thomas, 1950.)

1918 for meningitis and osteomyelitis were dreaded complications. During that presulfanilamide and preantibiotic era débridement might have caused his death through spread of infection.

Bone healing occurs best when immobilization is present and in the thoracic area there is considerable stabilization of the spine by the thoracic cage. As a result, in the patient in Case 1 fairly solid healing took place without too great bone overgrowth. This is extremely fortunate for there is proportionately less available space for the neural elements in the thoracic area then in other parts of the spinal canal. On the contrary, in the patient in Case 2 the bullet was lodged in the lumbar area where mobility is greater and consequently healing occurred with considerable osseous overgrowth and associated adhesions causing arachnoiditis and cauda equina compression. A greater degree of recovery may be expected in the region of the cauda equina for regeneration in nerve roots may occur if the anterior nerve neurilemmal sheaths have remained in continuity and there has not been complete neural destruction.

Old Stab Wound of the Spinal Cord

CASE 3*. H. S., a Negro man, forty-three years old, entered the University Hospital November 27, 1948, complaining of gradually progressive weakness of the left leg and increasing difficulty in the sexual sphere for nearly three years.

He had been stabbed in the back twenty-three years prior to admission. He had been able to walk to an automobile and was driven to a physician's office. There had been considerable loss of blood but no pain, paralysis, or other disability. On the following day he noted constant pain in the upper part of the back radiating through to the chest. It was not known whether he had fever at any time. He did not have a headache, stiff neck, or photophobia. Five weeks later the patient was able to return to light work. His left leg was slightly weak, but this disability completely disappeared three months after the injury and he was able to return to heavy labor.

* This case was reported by Rafael Castillo and E. A. Kahn. *In* Asymptomatic Transfixion of Spinal Cord by a Knife Blade. Report of a Case. J. Neurosurg., 7: 179-182, 1950. Springfield, Illinois, Charles C. Thomas. Its inclusion is by kind permission of the authors and publishers. An addendum is also presented.

No difficulty was experienced for thirteen years at which time he noticed that while dancing his coordination was not so good in his left leg as it was in the right. His sexual activity had remained normal until three years prior to admission when he noted that orgasm was more difficult although there were erections with normal voluptuous sensation. Simultaneously he noted increasing stiffness and weakness of the left leg which gradually progressed so that he walked with a limp. He had no urinary difficulty.

On examination the cranial nerves were intact. He had hypalgesia and hypaesthesia to the level of the fourth thoracic dermatome, which seemed more definite on the left side than the right. His deep pain sensation was diminished bilaterally, being more marked on the left side. Vibration sense was absent in the left ankle and diminished in the right. Position sense was intact bilaterally. Combined skin writing was recognized poorly throughout the entire trunk and extremities.

The patient walked with a distinct limp, having circumduction gait of the left leg. He had spastic monoplegia of the left lower extremity with atrophy and myokymic movements following exercise. He performed coordination tests with some ataxia on the left heel-to-knee test, probably as a result of weakness. The Romberg sign was within normal limits. The anal sphincter was intact. The deep reflexes were normal in the upper extremities but there was symmetrical hyperreflexia of the lower extremities with bilateral positive extensor plantar reflexes and left ankle and patellar clonus. Lumbar puncture was not performed.

Roentgenograms made of the thoracic spine showed a foreign body (broken knife blade), measuring approximately three inches in length, at the level of fourth thoracic vertebra, projecting through the spinal canal to the posterosuperior aspect of fourth thoracic vertebra, and lying just to the left of the mid-line (Figs. 3-A and 3-B).

At operation the fourth and fifth thoracic vertebrae were exposed. A discoloration was noted just to the left of the fourth spinous process. The upper part of the knife blade was exposed, grasped with forceps, and extracted with a moderate amount of force. A gush of dirty, rusty fluid was followed by a flow of cerebrospinal fluid. A meningocele sac had formed around the knife blade. The lamina of the third thoracic vertebra was removed exposing normal dura mater. Laminectomy was extended through the fifth thoracic vertebra where a mass of scar tissue was adherent to the dura mater in the mid-line—the site where the knife had been extracted. The dura mater was opened caudad without opening the arachnoid, and the scarred dura mater was excised leaving the arachnoid intact. A mass of gravish-black scar tissue seen in the center of the cord seemed to be well encapsulated, forming a sinus tract. The surrounding cord was softened and yellowed. A mass (0.8 by 2.0 centimeters) resembling a small, mid-line intramedullary tumor was completely removed. There was a defect, about four millimeters in length, in the spinal cord posteriorly, exactly at the mid-line. A small instrument could be passed through this defect downward to the anterior dura mater. It appeared as though the posterior columns had been completely destroyed. The lateral columns seemed intact. The attachment of one dentate ligament was divided so that the cord could be thoroughly explored. There was no question that the knife had passed completely through the center of the spinal cord. After careful hemostasis the upper and lower parts of the dural incision were closed, leaving a small defect which was covered with two separate layers of gelfoam. The wound was then closed in layers.

The patient did well postoperatively. He was able to move both legs although there was marked spasticity. Loss of vibration, position sense, deep pain, and skin writing perception was observed. His superficial touch was intact, but temperature and pain sensation were absent to a fourth thoracic dermatome level. There was retention of urine and he was maintained on intermittent bladder irrigation-drainage for six days after which there was normal bladder function. The patient was discharged twenty days after operation. He still had considerable weakness in both lower extremities but was able to walk with some assistance. At the time of re-evaluation, seven months after operation, he could walk by himself using one cane although there was some spasticity in both legs, perhaps most marked on the left. He had no extensor plantar reflexes bilaterally. Vibration and position sensations were present over the lower extremities. He had residual analgesia and thermodysaesthesia to the fourth thoracic dermatome level. He had erections without orgasm, and had good sphincter control. Fourteen months postoperatively he no longer needed a cane to walk on a flat surface. There was no improvement in his sensory status and sexual function.

Approximately six years later, on September 9, 1954, the patient was readmitted to University Hospital complaining of anorexia and abdominal fullness and tightness. He had vomited and had not had a bowel movement for three days. There was slight pain in the shoulder thirty-six hours prior to hospitalization. He had had no chills, fever, or night sweats. His blood pressure was 127 systolic and 76 diastolic, the pulse rate 88 per minute, and the respiratory rate 22 per minute. His lungs were clear on auscultation and his diaphragms high but moveable. He had marked abdominal distention, absence of bowel sounds, no palpable mass, and no localized or rebound tenderness. Rectal examination was within normal limits. On neurological evaluation he had hypalgesia and hypaesthesia to the sixth thoracic dermatome bilaterally. Position, vibration, and motion sense were present. He had

bilaterally hyperactive patellar and Achilles-tendon reflexes and a left extensor plantar reflex. Strength was markedly diminished in his left lower extremity and slightly reduced in the right one. His white blood count was 17,750. The urine contained an excessive amount of white blood cells. A roentgenogram of the chest showed a bilaterally elevated diaphragm. The flat roentgenographic plate of the abdomen revealed small bowel distention.

On September 9 a long intestinal tube was inserted and the bowel decompressed by the removal of 250 cubic centimeters of yellow fluid. The patient was given a barium enema which showed obstruction to retrograde flow at the splenic flexure. Later in the day a right cecostomy was attempted, and upon opening the abdomen frank pus was obtained from a perforated gangrenous appendix. No obstruction of the colon was found. The postoperative course was complicated by a right pleural effusion and postoperative atelectasis; however, on September 23, 1954, the patient was discharged from the hospital in good condition.

This case demonstrates that not only may a patient with a stab wound of the spinal cord live for many years before progression of symptoms occurs, but also indicates the importance of realizing that following such an injury pain sensation may be completely lost and that this loss may mask an acute abdominal catastrophe.

Antonelli reported removal of a knife blade from the thoracic spinal canal thirty-six years after the patient was stabbed. Jones presented a similar case twenty years after injury. In both of these instances the knife blade traversed the spinal canal without entering the substance of the cord and was removed at the time of laminectomy. Nina-Rodrigues published a case similar to Case 3 in which a file penetrating the spinal cord almost divided the lumen of the canal into two openings. The patient survived for twenty-eight years, finally dying of nephritis. According to the literature the man in Case 3 is apparently one of the few patients with an old stab wound to survive for a prolonged period, be operated upon, and to continue to live in an improved physical status.

In each one of the patients previously mentioned, a dirty gray or black staining of the cord was noted at the site of the stab wound. This was believed to be due to iron pigmentation, and dirty or rusty cerebrospinal fluid was found at the site of the wound. In discussing operative procedure on patients with late stab wounds of the spine and spinal cord, Rand and Patterson indicated that these patients may be helped ". . . by removal of thickened membranes and scar tissue about the cord at site of injury."

SUMMARY

The three cases herein reported demonstrate that early careful surgical removal of foreign bodies from the spinal canal with associated preoperative and postoperative antibiotic therapy is desirable in order to prevent chronic infection or increased bone overgrowth with its attendant spinal-cord compression.

REFERENCES

1. Antonelli, Giovanni: Paraplegia spastica insorta 36 anni dopo gli effetti immediati di una ferita da coltello della spina dorsale con permanenza del frammento infisso. Policlinico (sez. med.), **39**: 467-477, 1932.
2. Castillo, Rafael, and Kahn, E. A.: Asymptomatic Transfixion of Spinal Cord by a Knife Blade. Report of a Case. J. Neurosurg., **7**: 179-182, 1950.
3. Helfer, L. M.: Prolonged Spinal Cord Compression of Traumatic Origin. Report of Two Cases with Improvement Following Surgical Intervention. Southern Med. J.: **43**: 1027-1031, 1950.
4. Jones, W. A.: Old Stab Wounds of the Spinal Cord with Subsequent Widespread Pigmentation of the Spinal Cord and Base of the Brain. J. Am. Med. Assn., **121**: 1004-1006, 1943.
5. Key, J. A., and Conwell, H. E.: The Management of Fractures, Dislocations and Sprains. Ed. 6, p. 174. St. Louis, The C. V. Mosby Co., 1956.
6. MacCarty, C. S., and Mendelsohn, R. A.: Injury of the Cervical Vertebrae with Sequela after 50 Years. Proc. Staff Meet. Mayo Clin., **29**, 372-375, 1954.
7. Nina-Rodrigues: Un cas de blessure de la moelle épiniere par un instrument piquant. Ann. Hyg. Publ., **38**: 562-573, 1897.
8. Rand, C. W., and Patterson, G. H.: Stab Wounds of the Spinal Cord. Report of Seven Cases. Surg., Gynec., and Obstet., **48**: 652-661, 1929.

The Effect of Total Body Irradiation on Bone Transplants in Parabiosed Animals*†

BY WILLIAM F. ENNEKING, M.D., JACKSON, MISSISSIPPI,
AND AVRUM GRATCH, B.SC., CHICAGO, ILLINOIS

Previous studies in unselected female rats have shown that large fresh homogenous-bone transplants evoked a low-grade inflammatory response in the host tissues about the transplant [5]. This inflammatory response appeared between the seventh and fifteenth day after transplantation and became intense between the fifteenth and thirtieth day. After this period the intensity gradually abated but the inflammatory response persisted as a chronic granulomatous reaction until the transplant had been destroyed. In approximately two-thirds of the animals studied this inflammatory response effectively sequestered the transplant and prevented incorporation and replacement of the transplant by the host.

Fresh homogenous-bone transplantation was repeated employing the same donor and recipient animals. In those animals who had produced an inflammatory response to the first transplant, the second transplant evoked a more violent inflammatory response. The second response in these presensitized animals was more abrupt, more destructive, and more persistent than the original inflammatory reaction.

This sequence of events parallels closely the results obtained by other investigators employing primary and secondary skin transfers [14].

Animals were surgically joined and large fresh homogenous-bone transplants exchanged between members of the union. An acute inflammatory response sequestered the transplant in over 80 per cent of the animals. This inflammatory response closely resembled, in time and intensity, the inflammatory response observed in the presensitized animals who receive second transplants. Although one cannot precisely quantitate histological interpretation, a graphic summary of this work shows the general relationship between homogenous, presensitized homogenous, parabiotic, and control autogenous transplants (Chart I).

The rejection of homogenous transplants has received intensive study. The majority of investigators [2,5,14,17] conclude that the rejection mechanism resembles an antigen-antibody reaction. The homogenous transplant acts as the antigen. The precise constituents within the transplant which possess antigenic potency have not been determined. Although the defensive mechanism by which the host animal rejects the transplant is not known, the manner in which the transplants are rejected, the time at which they are rejected, and the repeated rejection of the same transplants at decreasing time intervals suggests that the host forms an acquired specific rejection mechanism against the transplant.

Many studies have been carried out in an attempt to show circulating antibodies formed against homogenous transplants. The great majority of these investigations have failed to demonstrate such antibodies [17]. These antibodies, found in the plasma proteins, presumably combine with the antigenic material within the transplant [2]. The reaction of this combination then produces a local inflammatory response which obliterates the blood supply to the transplant resulting

*Read in part at the Annual Meeting of The American Academy of Orthopaedic Surgeons, Chicago, Illinois, January 26, 1957, and at the Annual Meeting of The American Academy of Orthopaedic Surgeons, New York, N. Y., February 5, 1958. Given the Kappa Delta Award for Research in Orthopaedic Surgery.

†This investigation was supported by the United States Public Health Service Grant No. 1467 and the National Society for Crippled Children and Adults, Inc.

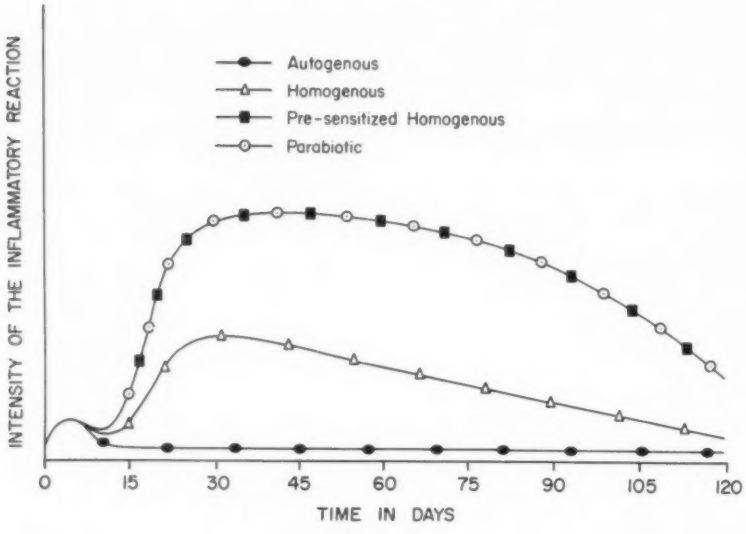


CHART I

in necrosis. Bonfiglio has demonstrated a weak titer of circulating antibodies in animals that had been immunized with extracts of homogenous bone. No relationship between these antibodies and the rejection mechanism was established.

Other investigators felt the rejection mechanism may occur as the result of cellular hypersensitivity [17]. In this phenomenon no circulating antibodies can be identified with any technique now available. The tuberculin reaction is an example of cellular hypersensitivity.

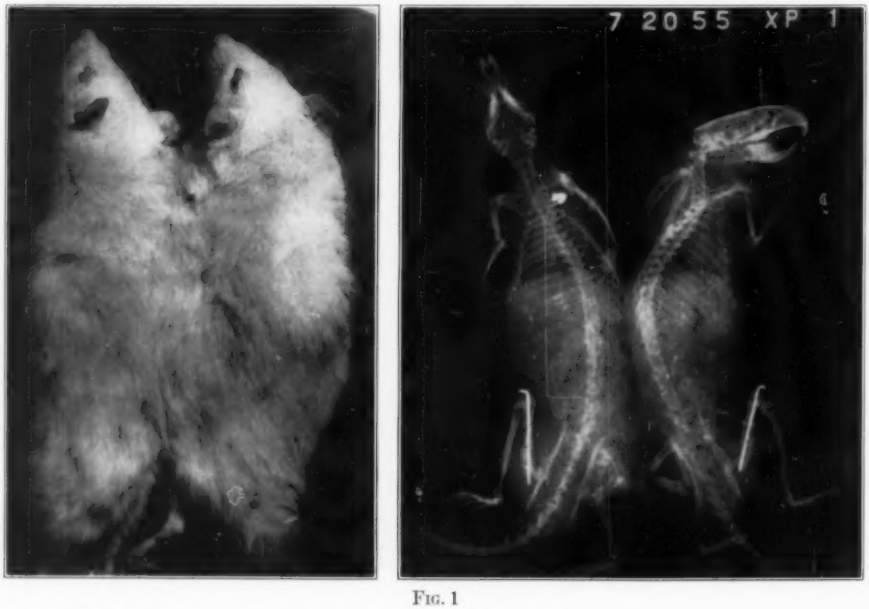


FIG. 1

Parabiosis (reproduced from The Journal of Bone and Joint Surgery, **39-A**: 598, June 1957).

Whether one or both of these mechanisms is responsible for the rejection of the homogenous transplant has not been established. Investigation has shown that total body irradiation does suppress the production of circulating antibodies [18]; its effect on cellular hypersensitivity is less certain. The survival of homogenous-skin transplants has been prolonged in mice and rabbits that received total body irradiation prior to receiving the transplants [4,9]. Presumably, this enhancing phenomenon is related to the suppression of the immunological defensive mechanism in the irradiated host.

The present experiments were made to determine the effect of total body irradiation upon the survival of homogenous-bone transplants exchanged between surgically united rats.

Parabiosis was originally described by Bert in 1864 (Fig. 1). He felt that one partner acted as the donor and one as the recipient and that this procedure was homogenous-bone grafting. He determined that the rat was the most complex animal in which long-time survival followed surgical parabiosis. Bert showed by intravenous injection of dyes that a common circulation existed between the joined animals. He, however, did not record the mortality rate of the animals used in this procedure.

Parabiosis is produced by establishing a common peritoneal cavity, suturing the adjacent scapulae, and joining the dorsal and ventral skin flaps. The animals so united tolerate this procedure well and live in harmony for the first ten postoperative days. In the following ten days there may develop a condition known as parabiotic intoxication in which one member of the union becomes smaller, anaemic, emaciated, and may die. Examination of both partners following death of one from parabiotic intoxication reveals in the surviving animal a great increase in the lymphoid tissue while in the intoxicated animal there is extreme atrophy of the lymphoid tissue and the adrenal glands [15]. This intoxication is thought to be a constitutional incompatibility manifested by an immune reaction [7].

Parabiotic intoxication causes death of one member in 65 to 70 per cent of the unions when rats of the same sex, but selected at random, are used. When littermates are selected for members of the union the incidence of fatal parabiotic intoxication is reduced to 30 to 50 per cent [6,8].

Animals that survive the initial immunological response to one another flourish and may live harmoniously in parabiosis as long as two years. Delayed parabiotic intoxication occurs, but is unusual. There is a common circulation between parabiotic partners. This has been redemonstrated by injection of foreign red blood cells, injection of radiopaque substances, and injection of isotope-tagged red blood cells. It has been determined quantitatively that 0.66 per cent of the blood volume per minute is transferred from one animal to the other [10].

Parabiosis has been employed as an experimental tool in many physiological investigations in which humoral transmission plays a part. Evidence from these diverse experiments relates to the problem of homogenous-tissue transplantation. It has been shown that biologically active antibodies pass from one member of a parabiotic union to the other. This transfer of antibodies has been utilized in the study of active and passive immunity in various infectious diseases [16].

Parabiosis has also been directly employed in the study of transplantation. When animals of the same genetic strain are used in parabiosis the union thus formed is referred to as an isogenic union. These unions are produced by joining littermates of inbred strains. Kamrin has shown that renal transplants between surgically united littermates survive and function. When animals which are selected at random and are genetically unrelated are joined in parabiosis their survival rate is low. The unions thus produced are termed non-isogenic parabionts. Renal transplants exchanged between non-isogenic parabionts are obliterated in an accelerated fashion by an acute inflammatory reaction [13]. It appears then that isogenic parabionts do not form a rejection mechanism against transplants from their partners while non-isogenic parabionts form an accelerated rejection mech-

FIG. 2

Full circumference femoral-shaft transplant (reproduced from The Journal of Bone and Joint Surgery, **39-A**: 598, June 1957).

anism. Work cited earlier[5] has also shown an accelerated rejection mechanism between non-isogenic parabionts in response to bone transplants.

In light of the previously cited investigations it was felt that if one member of a non-isogenic parabiotic union received total body irradiation while the other member was shielded from the x-rays, a situation would exist in which the non-irradiated animal would be capable of producing a rejection mechanism against its partner while the irradiated animal would be incapable of forming this mechanism. If a relationship exists between antibody formation and the accelerated inflammatory response to homogenous-bone transplants there might be a detectable difference in the host response to transplants in this experimental situation. The irradiated animal, being immunologically paralyzed, should be incapable of forming a rejection mechanism against the homogenous transplant. The non-irradiated animal, being immunologically active, should show the previously described accelerated inflammatory response to the homogenous transplant.

The variables in this experiment were the amount of depression of the rejection mechanism produced by the dose of irradiation, the degree of incompatibility of the animals selected as partners for parabiosis, and the effect of radiation upon bone repair. The variability of the depression of the immuno-

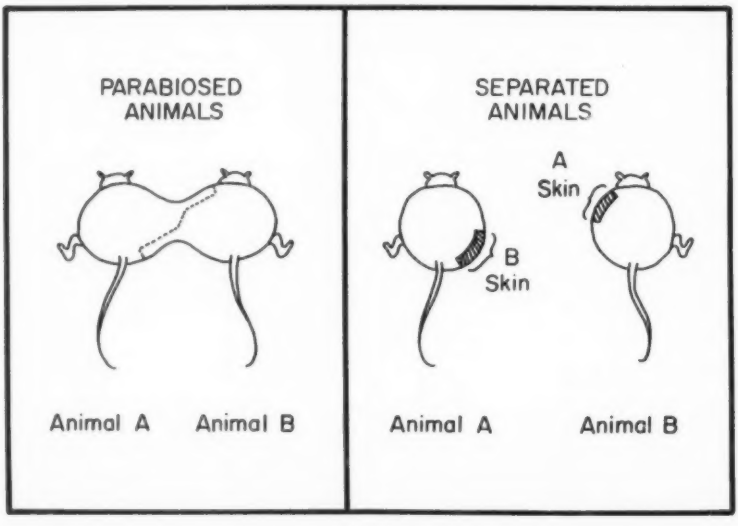


FIG. 3

Pedicle based full-thickness skin transplants.

logical mechanism was minimized by giving heavy and regularly repeated doses of radiation.

The incidence and site of fatal parabiotic intoxication furnished a control for the effectiveness of the dosage.

Animals selected at random and produced by random mating were used as partners to minimize the chance occurrence of isogenic pairs. The animals were tested by skin transplants after the completion of the bone transplants for isogenicity.

Comparison of the non-irradiated and the irradiated animals served as a control in evaluating the effect of radiation upon bone repair.

METHOD

One-hundred-gram female Sprague-Dawley rats received total body irradiation as follows:

Target distance, fifty-five centimeters; filtration, 0.5 millimeter copper and one millimeter aluminum; energies, 250 KVP—17.5 milliamperes; dose rate, 57.6r per minute; dose delivered, 100r; and time, one minute, forty-four seconds. These animals were surgically united with non-irradiated rats of the same size and sex forty-eight to seventy-two hours following their initial irradiation. The dose of total body irradiation was repeated at seven-day intervals throughout the course of the experiment to the irradiated member of the union while shielding the non-irradiated animal. Full circumference sections of the femoral shafts with attached periosteum were exchanged twenty-four to thirty-five days after parabiosis and immobilized by an intramedullary wire (Fig. 2). Full-length sagittal sections of the femur were subsequently obtained by disarticulation at the hip and prepared for histological study.

The surviving surgically united animals were maintained for six months or longer without radiation following completion of the bone experiments. They were then surgically separated in such a fashion that a broad-based pedicle of skin and subcutaneous tissue from one animal was incorporated as a portion of the integument of its partner (Fig. 3).

RESULTS

A total of 373 parabiotic unions were prepared. One or more members of eighty-one unions died of shock or overdose of anaesthesia. In sixty-one unions, one or both members died from infection, evisceration, or trauma. Of the remaining 231 unions, in ninety-nine, one member died of parabiotic intoxication between the tenth and twenty-first day after union. In all but three of these unions, death occurred in the irradiated member. The incidence then of fatal parabiotic intoxication in those animals who survived ten days was 43 per cent. The animals in ten unions died twenty-one days after union of infection or unknown causes. Thus, of the original 373 unions, the animals in 118 survived and had bone transplants exchanged between them. Of these animals, 104 preparations from fifty-two pairs were studied.

There was no detectable difference in the healing of the clean surgical wounds produced by parabiosis or transplantation in the irradiated animals as compared with the non-irradiated animals. There was, however, a significant increase in the incidence of indolent wound infections in the irradiated animals.

Histological studies of the bone preparations obtained prior to seven days after transplantation showed no significant difference in response between the irradiated and non-irradiated animals.

The preparations obtained from the forty-seven unions sacrificed after the seventh day and up to the 120th day following bone transplantation showed two divergent circumstances.

In sixteen of the unions the irradiated animal did not produce an inflammatory response to the transplant while the non-irradiated animal did produce an inflammatory response which was sufficient to sequestrate the transplant from the reparative processes (Figs. 4-A through 5-B).

FIG. 4-A

FIG. 4-B

Figs. 4-A and 4-B: Thirty-day irradiated parabiont.

Fig. 4-A: The low-power frame shows the transplanted cortex in the upper half of the frame with periosteal new bone along its outer margin. The host cortex in the lower half of the frame abuts the transplant cortex and also has new repair bone along its outer margin. The two areas of new repair bone which have formed in relation to both host and transplant bone are united by an intervening zone of fibrocartilage which surrounds the host-transplant junction. No inflammatory response is seen.

Fig. 4-B: The higher-power frame shows the free margin of the transplant with the new periosteal repair bone united to it.

FIG. 5-A

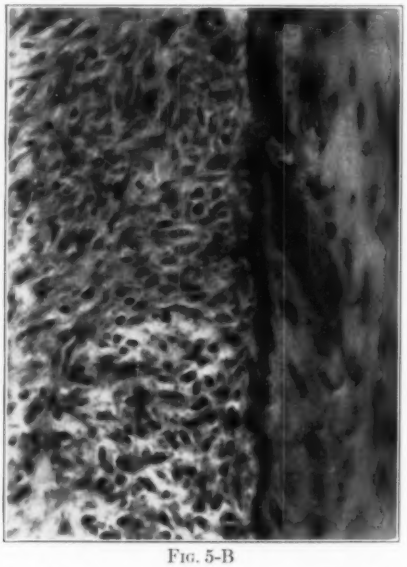


FIG. 5-B

Figs. 5-A and 5-B: Thirty-day non-irradiated parabiont (partner of parabiont in Figs. 4-A and 4-B).

Fig. 5-A: The lower-power frame shows the transplanted cortex in the upper half of the frame enveloped in chronic inflammatory tissue. The host cortex in the lower half of this frame abuts the transplant cortex and is surrounded by periosteal repair bone on its free margin. The

transplant cortex is sequestered from the repair processes by the chronic inflammatory tissue encapsulating it.

Fig. 5-B: The higher-power frame shows the transplanted cortex enveloped by chronic inflammatory cells.

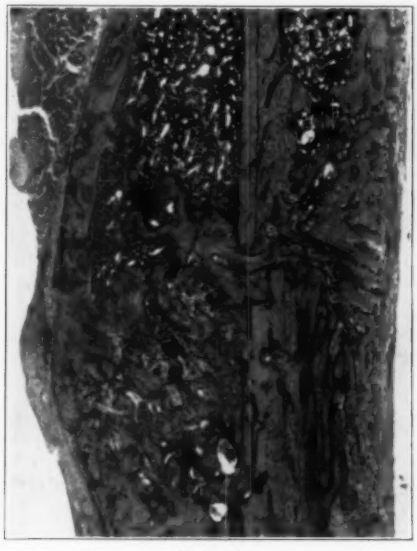


FIG. 6-A

FIG. 6-B

Figs. 6-A and 6-B: Thirty-day irradiated parabiont.

Fig. 6-A: The lower-power frame shows the transplanted cortex in the upper half of the frame with periosteal repair bone along its free margin. The host cortex in the lower half of this frame is also enveloped in periosteal repair bone. There is union of the repair bone about the host-transplant junction. No inflammatory response is seen.

Fig. 6-B: The higher-power frame shows the transplant cortex united to the new periosteal repair bone.

In twenty-eight of the unions neither the irradiated animal nor the non-irradiated animal produced an inflammatory response to the transplant (Figs. 6-A through 7-B).

There were three unions in which the irradiated animal produced an inflammatory response.

Twenty-four of the above forty-seven pairs survived six months after bilateral hip disarticulation. Separation with skin transplantation was accomplished in these animals. Fourteen animals died as an immediate result of the procedure. Five animals showed necrosis of the transplanted skin within forty-eight hours of transfer. Four animals from two pairs accepted the skin from their partners with survival of the skin to the time of writing or to their demise (Figs. 8-A and 8-B). Twenty-five animals showed survival of the transplanted skin for a period ranging from six to twelve days after separation. Inflammation then developed about the transplants and necrosis followed in three to five more days. Biopsies of these skin transplants made three to five days following separation and prior to the onset of necrosis showed patent vascular supply with no deep necrosis (Figs. 9-A through 10-B).

DISCUSSION

The decrease in the incidence of parabiotic intoxication from 70 per cent to 43 per cent in this laboratory when one member was irradiated preoperatively agrees with the experience of other investigators [6,8]. This decrease is evidence of the effectiveness of total body irradiation in suppressing immunological reactions.

FIG. 7-A

FIG. 7-B

Figs. 7-A and 7-B: Thirty-day non-irradiated parabiont (partner of parabiont in Figs. 6-A and 6-B).

Fig. 7-A: The lower-power frame shows the transplant cortex in the upper half of the frame enmeshed in the new periosteal repair bone. The host cortex in the lower half of the frame is similarly enveloped by periosteal repair bone. The two areas of repair bone are united by a zone of fibrocartilage at the host-transplant junction. No inflammatory response is seen.

Fig. 7-B: The higher-power frame shows the transplant cortex united to the periosteal repair bone. Note the beginning process of replacement and repair of the cortical bone from and by the periosteal repair bone.

FIG. 8-A

FIG. 8-B

Figs. 8-A and 8-B: Acceptance of homogenous-skin transfer from a parabiotic partner.

Fig. 8-A: The host skin below the scar and the transplanted skin above the scar nine days after separation.

Fig. 8-B: The same area seventy-five days later.

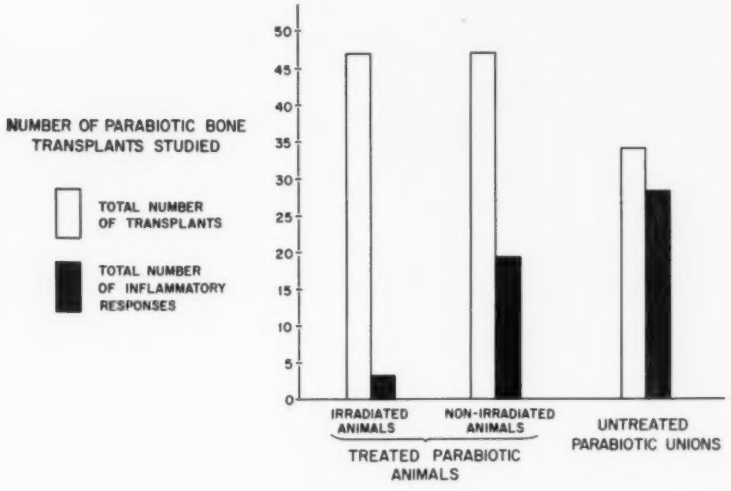


CHART II

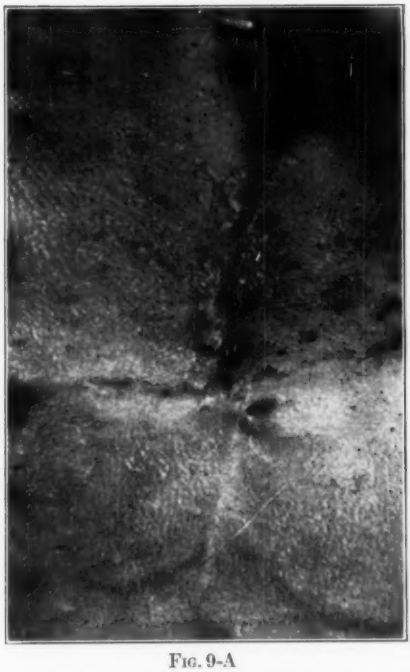


FIG. 9-A

FIG. 9-B

Figs. 9-A and 9-B: Delayed slough of homogenous-skin transfer from a parabiotic transfer.
Fig. 9-A: The host skin below the scar and the transplanted skin above the scar, three days after separation.
Fig. 9-B: Biopsy specimen with the host skin in the lower half of the frame and the transplanted skin in the upper half of the frame.

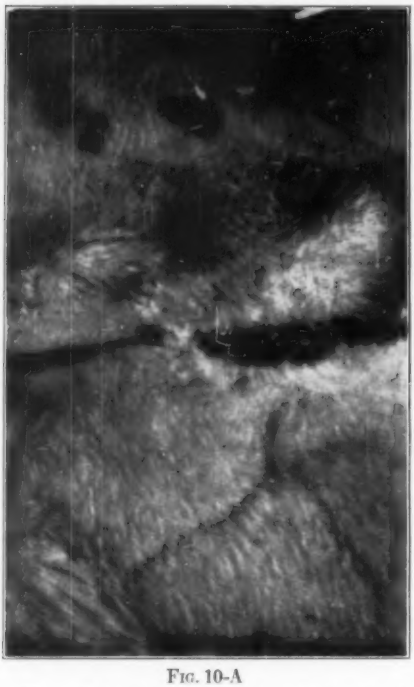


FIG. 10-A

FIG. 10-B

Figs. 10-A and 10-B: Delayed slough of homogenous-skin transfer from a parabiotic transfer.

Fig. 10-A: The host skin below the scar (indicated with India ink) and the transplanted skin above the scar nine days after separation.

Fig. 10-B: Biopsy specimen with the host skin in the lower half of the frame and the transplanted skin in the upper half of the frame.

It is worthy of note that 96 per cent of the fatal intoxications in these experiments occurred in the irradiated animals.

The amount of radiation given during this period was less than 60 per cent of the lethal dose. In the study of radiation toxicity in animals there has developed a large body of evidence pointing to a humoral factor which affords a significant degree of protection, treatment, or both for animals that have received a lethal dose of radiation. This factor is apparently elaborated by the spleen and transmitted by the blood stream [11]. It has been noted that the spleen of one member of a parabiotic union will afford protection to the other member following a lethal dose of radiation [3]. In rats this humoral factor permits regeneration of the blood-forming elements following irradiation in approximately six days. In the absence of this factor death ensues from aplastic anaemia. In the present experiments the irradiated animal had the spleen of the other member of the union as added protection. It is felt that the high mortality in the irradiated animals is not the result of radiation toxicity. It appears more likely that the irradiated animal was the site of intoxication because of the intact rejection mechanism in the non-irradiated animal. Conversely, the non-irradiated animals may have escaped intoxication because the irradiated animal was incapable of forming a rejection mechanism.

The increase in indolent wound infection in the irradiated animals provides further evidence of the effectiveness of the irradiation dosage in suppressing the immunological mechanism.

The absence of an inflammatory response to the homogenous-bone transplant

in over 95 per cent of the irradiated animals suggests there is a relationship between the suppression of the rejection mechanism and the decreased incidence of inflammatory response to homogenous-bone transplant.

The absence of an inflammatory response to the transplant in almost 60 per cent of the non-irradiated animals was unexpected. This finding might suggest that the incidence of inflammatory response to homogenous-bone transplants in untreated surgically united animals determined in a previous experiment (80 per cent) was too high. However, the total number of animals in each group in that experiment exceeded thirty, which is statistically significant above a 5 per cent level. A possible explanation might be that the suppression of the immunological response by irradiation is mediated through a humoral mechanism which is to some extent effective in both members of the union through their common circulation.

Only a small number of animals survived irradiation, parabiosis, homogenous-bone transplantation, hip disarticulation, six months convalescence, separation, and skin transplantation. This precludes a definite statement concerning the number of isogenic pairs occurring in the animals selected at random. However, after release from the temporary immunological suppression, 86 per cent of the animals rejected exchange skin transfers. These animals had been surgically united for periods of nine to seventeen months. This would suggest that the random selection of animals did produce a high percentage of non-isogenic pairs. In this light it appears highly unlikely that isogenicity played a significant role in the results of the experiment (Chart II).

There was no detectable difference in the healing of the large homogenous-bone transplants that did not produce an inflammatory response as compared with autogenous-bone transplants produced in a like manner.

SUMMARY

Total body irradiation appears to be effective in blocking the rejection mechanism to large fresh homogenous-bone transplants in surgically united rats. The precise mechanism of this effect is not understood.

REFERENCES

1. Bert, Paul: Expériences et considérations sur la greffe animale. J. Anat., **1**: 69-87, 1864.
2. Bonfiglio, Michael; Jeter, W. S.; and Smith, C. L.: The Immune Concept: Its Relation to Bone Transplantation. Ann. New York Acad. Sciences, **59**: 417-442, 1955.
3. Brecher, G., and Cronkite, E. P.: Post-Radiation Parabiosis and Survival in Rats. Proc. Soc. Exper. Biol. and Med., **77**: 292-294, 1951.
4. Dempster, W. J.; Lennox, B.; and Boag, J. W.: Prolongation of Survival of Skin Homotransplants in the Rabbit by Irradiation of the Host. British J. Exper. Pathol., **31**: 670-679, 1950.
5. Enneking, W. F.: Histological Investigation of Bone Transplants in Immunologically Prepared Animals. J. Bone and Joint Surg., **39-A**: 597-615, June 1957.
6. Finerty, J. C.: Personal communication.
7. Finerty, J. C.: Parabiosis in Physiological Studies. Physiol. Rev., **32**: 277-302, 1952.
8. Finerty, J. C., and Panos, T. C.: Parabiosis Intoxication. Proc. Soc. Exper. Biol. and Med., **76**: 833-835, 1951.
9. Hardin, C. A., and Werder, A. A.: The Effect of Total Body Irradiation on the Survival of Homologous Skin Grafts on CFW Mice. Plast. and Reconstruct. Surg., **13**: 40-45, 1954.
10. Huff, R. L.; Trautman, R.; and Van Dyke, D. C.: Nature of Exchange in Parabiotic Rats. Am. J. Physiol., **161**: 56-74, 1950.
11. Jacobson, L. O.: Evidence for a Humoral Factor (or Factors) Concerned in Recovery from Radiation Injury: A Review. Cancer Res., **12**: 315-325, 1952.
12. Kamrin, B. B., and Kamrin, R. P.: Auto and Homotransplantation of Kidney Tissues in Single and Parabiotic Albino Rats. Anat. Rec., **122**: 223-240, 1955.
13. Lang, Stanley; Dammin, G. J.; and Miller, B. F.: Transexplantation of Rat Kidneys in Parabiotic and Pseudoparabiotic Animals. Ann. New York Acad. Sciences, **59**: 401-408, 1955.
14. Medawar, P. B.: The Behaviour and Fate of Skin Autografts and Skin Homografts in Rabbits. J. Anat., **78**: 176-199, 1944.
15. Nissen, Rudolf: Überfibrösen Knochenmarksersatz. (Unter Benutzung des Parabioseversuches.) Deutsche Zeitschr. f. Chir., **191**: 197-220, 1925.
16. Tani, T., and Aikawa, S.: Das Wesen der Syphilisimmunität. III. Mitt. Parabioseversuche mit Kaninchen. Japanese J. Exper. Med., **14**: 465-481, 1936.

17. VOISIN, G. A., and MAURER, P.: Studies on the Role of Antibodies in the Failure of Homografts. Ann. New York Acad. Sciences, **64**: 1053-1073, 1957.
18. WISSLER, R. W.; ROBSON, M. J.; FITCH, F.; NELSON, W.; and JACOBSON, L. O.: The Effects of Spleen Shielding and Subsequent Splenectomy Upon Antibody Formation in Rats Receiving Total-Body X-Irradiation. J. Immunol., **70**: 379-385, 1953.

DISCUSSION

DR. CHARLES H. HERNDON, CLEVELAND, OHIO: I have, for several years, been actively engaged in studies of the immunological factors in homogenous-bone transplantation and have learned that the technical problems involved often exceed the scope of my knowledge of immunology and chemistry. This is true with Dr. Enneking's presentation and I have, therefore, in evaluating his results, sought the advice of Dr. Arnold Powell, the immunochemist who is collaborating with me in my studies.

Dr. Enneking has three major variables which must be considered independently in evaluating his results: irradiation, parabiosis, and transplantation of bone.

The depression of the immune response by radiation is well documented but it is not 100 per cent effective for complete depression and it is temporary in effect. This variable Dr. Enneking combats by rather heavy irradiation and repetition of the dosage.

With respect to the parabiosis variable, it must be kept in mind that the situation is quite different in isogenic pairs and in non-isogenic pairs. In isogenic pairs coupled in parabiotic union survival is more frequent, there is neither hereditary nor immunological incompatability, no antibodies should be formed in either animal, and irradiation should not affect this relationship. In non-isogenic pairs, however, the survival rate would be less, there may be immunological incompatibility, many antibodies would be formed, and one or both animals would be injured. If then, the non-isogenic pairs are joined in parabiosis and one of the animals irradiated, the irradiated animal is the one that dies as noted by Dr. Enneking. If we designate the non-irradiated animal as N and the irradiated animal as R we can then describe the mechanism as follows: N receives a complex organ transplant from R; N makes an anti-R antibody which injuries R and R dies. At the same time, R has received a similar complex organ transplant from N, but R was irradiated and cannot make antibodies; therefore, the only antibody circulating in the union is anti-R. As there is no anti-N, there is no cytotoxic effect in N and N survives.

If we now combine all three variables—parabiosis, irradiation, and transplantation—there are a number of important points that must be kept in mind. It is well established that when tissues are transplanted in isogenic pairs, the transplants are usually tolerated; therefore, irradiation would have no effect in such a situation. Similarly, it is apparent that isogenic parabiotic pairs should tolerate mutual transplants whether irradiated or not. In non-isogenic pairs, however, tissue transplants are known to be rejected while irradiation enhances the survival of the transplant. In Dr. Enneking's parabiotic animals, if we again designate the non-irradiated animal N and the irradiated animal R, the bone from R transplanted into N apparently induces anti-bone R antibodies which produces an inflammatory reaction at bone R in animal N. Bone N transplanted into animal R does not induce antibodies as R was irradiated. Therefore, in both animals there was only one anti-bone antibody, anti-R. One would question, however, why the anti-bone R could not return to animal R and injure R bones, as covascularity was demonstrated by Dr. Enneking. The lack of damage to bone in animal R suggests that the antibody was not circulating.

It is also to be noted that exactly similar results observed in Dr. Enneking's parabiotic animals should hold in non-parabiotic pairs; that is, bone from R transplanted to N would induce anti-R which would lead to rejection of the transplant while bone from N transplanted to R could not induce anti-N as R was irradiated and the transplant would survive. One would question, therefore, if Dr. Enneking has demonstrated the presence of a circulating antibody through the use of the parabiosis technique.

It is of interest that eighteen pairs of rats showed transplant acceptance in both the irradiated and non-irradiated animals. This may well have been due to selection of the rats. If isogenic pairs were used, these results would be anticipated. I should like to ask Dr. Enneking if the heredity of the rats used was known well enough to be sure whether they were truly isogenic or non-isogenic.

DR. C. ANDREW L. BASSETT, NEW YORK, N. Y.: The experimental design of the paper seems adequate to provide the results described and to justify the conclusion. One wonders if the transplantation of any free-bone graft with periosteum attached does not augur poorly for rapid graft revascularization and incorporation. However, in this particular study the presence of periosteum on the graft is probably of minor significance and does not invalidate or alter the findings.

From this and preceding papers, it is apparent that a fresh homogenous-bone graft is rejected by the same mechanism that destroys fresh homogenous-bone grafts of all other tissues with the possible exception of cornea. The mechanism probably involves an immune response on the part of the host and perhaps even on the part of the graft. In all probability

foreign proteins, nucleoproteins, or mucopolysaccharides within the graft or elaborated by the metabolism of its cells may act as antigens. The wider the genetic incompatibility between donor and host, the greater the number of foreign-tissue components, the greater the potential number of antigens, and the greater the ultimate immune response. From a practical standpoint grafts between homozygous twins or animals of a highly inbred strain can be expected to behave as autogenous-bone grafts and permanently survive transplantation. On the other hand, cross species grafting (heterogenous bone-grafting) evokes the most intense inflammatory rejections.

The recent illuminating findings of Algire and his co-workers at the National Cancer Institute resolve some of the enigmas of the homogenous-bone graft response. For years investigators have sought unsuccessfully to demonstrate a suspected immune mechanism by searching for circulating antibodies. Algire has now shown that the antibodies responsible for graft rejection are probably bound to the membranes of mononuclear cells of the blood and do not circulate in the free state. His work has further shown that the host may deal in a different way with the cross species graft. Probably because of wide genetic incompatibility, heterogenous-bone grafts evoke circulating antibodies and are destroyed even in a cell-free system.

There are three ways for altering the immune response to homogenous-bone grafts. First, the graft may be conditioned by removing potential antigenic material from the donor tissue or by using embryonal tissue at a time when potential antigens are low in concentration. This method has been successfully applied by Gaillard, Hurley, and others. Second, the immune response apparatus is immature in the fetal and neonatal mammal. It is therefore often incapable of meeting the immunological challenge posed by a homogenous-bone graft. Longmire, Billingham, Medawar, and others have made use of this factor in altering rejection of the homogenous-bone graft. The third method of alteration has been used by the present authors and involves blocking the host's antibody production. Total body irradiation, corticoids, or reticulo-endothelial blocking agents can paralyze the immune response. With such an approach normal and neoplastic grafts of homogenous and heterogenous tissue have been successfully carried out by Toolan, Howes, and others.

In closing the discussion, allow me to shift emphasis to a clinical level. There is little question of the superiority of the fresh autogenous-bone graft in orthopaedic surgery. However, most of us will admit that the homogenous-bone graft serves a most useful function under the proper circumstances. The majority of preserved homogenous-bone grafts are not alive and if not too chemically altered by preservation, evoke a minimal inflammatory response. Experimentally preserved, non-viable, homogenous-bone grafts follow the same pattern of host incorporation as autogenous-bone grafts with the exception that the rate is initially a little slower. These observations, coupled with the 85 to 95 per cent success rate reported with bone-bank bone, argue strongly in favor of the continued clinical use of properly preserved homogenous-bone grafts in selected cases.

DR. ENNEKING (closing): Dr. Herndon has immediately gone to the nub of the problem with which I have wrestled for some time. In regard to the hereditary charts of the animals used, we have no definite or specific information. There were over 600 pairs of animals used in the experiments. We received these over a period of four years in random shipments from a single breeder and I cannot answer the question as to specific hereditary background.

We make no claim that we have identified an antibody which has formed in response to homogenous transplant. We do not understand what we have done; we wish that somebody would tell us. We merely observed that when we irradiated the animals something happened that did not happen when we did not irradiate them and we feel that it is due to the irradiation. Other than that we do not know anything more than when we started.

Congenital Posterior Angulation of the Tibia with Talipes Calcaneus

A Long-Term Report of Eleven Patients

BY CLARENCE H. HEYMAN, M.D., CHARLES H. HERNDON, M.D., AND KINGSBURY G. HEIPLE, M.D., CLEVELAND, OHIO

From the Services for Crippled Children, Elyria Memorial Hospital, Elyria

In 1949 the authors described three cases of congenital posterior or posteromedial angulation of the tibia with talipes calcaneus, and suggested that this deformity was as a clinical entity entirely distinct from congenital bowing of the tibia with anterior convexity. These three patients were treated conservatively

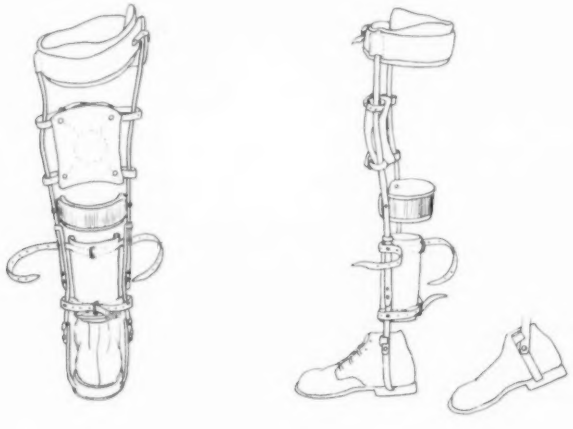


FIG. 1

Drawing of the brace used in the treatment of congenital posterior angulation of the tibia with talipes calcaneus. The uprights extend from the heel of the shoe to the hip. The stop-joint at the ankle prevents dorsiflexion but permits plantar flexion. The wide posterior leather band, tightened by straps and buckles, exerts pressure or support against the posterior convexity of the curve of the tibia. A free joint at the knee is provided when the leg grows sufficiently long to make this practical.

without osteotomy; gradual correction of the deformity occurred during growth, with no residual disability other than a persistence of some tibial shortening.

A clinical classification of the congenital angulations of the tibia into three groups was made in which angulations with a posterior or posteromedial convexity were separated from the angulations with anterior convexity. The characteristics of each group were described. Group I consisted of the anterior angulations associated with pseudarthrosis or fracture with non-union; Group II consisted also of anterior angulations, but accompanied by talipes equinus, usually with concomitant absence of the fibula and other anomalies of development; Group III consisted of posterior or posteromedial angulations with talipes calcaneus.

The characteristics of Group III, the subject of this report, are:

FIG. 2-A

Case 1, M.S., April 6, 1941, at the age of eight months. There was severe posteromedial bowing of the left tibia and fibula at the junction of the middle and lower thirds. There was shortening of one inch.

FIG. 2-B

May 23, 1958, at seventeen years and nine months of age. Epiphyseodesis at the upper tibial and fibular epiphyses of the right leg was done at the age of eleven years and seven months—too late to be of any benefit. Fusion of the epiphysis of the tibia was asymmetrical.

1. Posterior angulation or backward and medial bowing at the junction of the middle and lower thirds of the diaphysis of the tibia, with similar bowing of the fibula.

2. Severe talipes calcaneus.

3. Tightness of the anterior muscles of the leg and weakness of the triceps surae.

4. Presence of a dimple over the apex of the angulation.

5. Shortness of the lower extremity confined chiefly, if not entirely, to the leg, and underdevelopment of the muscles of the leg.

6. No detectable abnormality of the structure of the bone, other than a thickening of the cortex on the concave side of the curve.

7. No appreciable impairment of the upper or lower tibial epiphysis.

8. No unusual tendency to fracture.

9. Good prognosis with conservative treatment.

The purpose of this paper is to present a long-term report of the three patients described in 1949 and to record the findings in eight additional patients who have been under our treatment or close observation since that time. All eleven patients have been under observation from infancy to the time of writing. Their ages range from four to eighteen years. We examined roentgenograms and received records of several other unreported cases, but are not including these because of insufficient information concerning treatment or results. We have also made a thorough search of the literature, attempting to collect all reported cases of congenital posterior angulation of the tibia, and are appending the pertinent references.

The incidence of congenital posterior angulation of the tibia is not so rare as was thought. Although we know of only three cases reported in the English literature before 1949, we have now learned that several foreign writers did describe a total of twenty-six cases. Little note was made, however, of co-existing talipes calcaneus or of the other characteristics which identify this deformity as a

FIG. 3-A

FIG. 3-B

FIG. 3-C

Fig. 3-A: Case 2, A.W., September 18, 1942, at six weeks of age. There was severe posterior and medial angulation of the right tibia and fibula at the junction of the middle and lower thirds.

Fig. 3-B: December 7, 1945, at the age of three years.

Fig. 3-C: March 24, 1948, at five and one-half years of age. The bowing had almost disappeared. There was shortening of one and one-quarter inches.

FIG. 3-D

April 18, 1958. Both legs at sixteen years and three months of age. There was only a slight medial curve of the tibia.

FIG. 3-E

Photographs made April 18, 1958. The leg was straight. Epiphysiodesis at the upper left tibial and fibular epiphyses was done at the age of eight years when there was shortening of one and one-half inches. Shortening on this date was only one-half of an inch.

separate entity. During the last nine years twenty-nine more cases were reported, twenty-five of which are in the English literature. Including the eleven cases in this report, at least sixty-nine cases are now recorded in the literature. The results of treatment were reported in fifty-seven cases; they were good in the forty-eight treated conservatively and union occurred in nine treated by osteotomy of the tibia. Shortening persisted in all as the leg became straight, whether the patients were treated conservatively or by osteotomy. No appreciable stimulation of growth in length was induced by osteotomy, as sometimes occurs in children after fracture.

FIG. 4-A

Case 3, T.D., December 3, 1943, when four weeks old. There was moderately severe angulation of the left tibia.

FIG. 4-B

May 23, 1958. Both legs at the age of fourteen and one-half years.

All of our eleven patients were treated conservatively. Therapy during the first few months after birth was directed only to the severe calcaneus, and consisted in massage and stretching of the soft tissues which held the foot in calcaneus. In some cases a simple molded plaster splint over the anterior aspect of the leg and dorsum of the foot was applied while holding the foot in plantar flexion. This plaster splint was held in place by an elastic bandage. It was removed by the mother for the manipulations of the foot and ankle, and then reapplied. A brace was applied as early as practical—at about five or six months of age, or just

TABLE I

Patient	Sex	First Examination (*Age and Date*)	Brace Applied (*Age and Date*)	Brace Worn (*Duration*)	Shortening (*Inches*) 3 yrs.	6 yrs.	9 yrs.	12 yrs.	15 yrs.	Last Examination (*Age and Date*)	Present Deformity
1. M.S.*	F	6 wks. (10/17/40)	6 mos. (5/5/41)	3 yrs.	1	1¼	1¾	1¾	1½	18 yrs. (6/26/58)	None (Figs. 2-A and 2-B)
2. A.W.**	F	3 wks. (9/4/42)	5 mos. (2/5/43)	3 yrs., 9 mos.	1	1¼	1½	1	½	16 yrs., 3 mos. (4/18/58)	None (Figs. 3-A through 3-E)
3. T.D.	M	4 wks. (12/3/43)	10 mos. (9/20/44)	1 yr., 10 mos.	1	1	1	1¼	1¼	14 yrs., 10 mos. (9/26/58)	Minimal or none (Figs. 4-A and 4-B)
4. R.R.	M	3 wks. (8/3/45)	9 mos. (5/3/46)	5 yrs., 10 mos.	1¼	1¼	1¼	1¾		12 yrs., 8 mos. (4/18/58)	Very mild
5. T.P.	M	4 mos. (1/6/48)	8 mos. (9/ /48)	2 yrs.	½	½	1			9 yrs., 6 mos. (7/8/57)	Very slight
6. J.M.	M	1 day (9/16/49)	7 mos. (4/23/50)	2 yrs.	1½	?	2			8 yrs., 4 mos. (1/17/58)	None
7. B.A.	M	1 day (9/8/50)			1¼	1⅜	1½			8 yrs. (8/3/58)	None
8. D.H.	M	4 wks. (7/20/51)	4 mos. (11/ /51)	1 yr., 6 mos.	½	¾				6 yrs., 9 mos. (4/18/58)	Mild (Figs. 5-A through 5-E)
9. J.H.***	M	1 day (9/10/51)	6 mos. (3/1/52)	5 yrs.	1¼	1⅜				6 yrs., 6 mos. (3/14/58)	Practically none (Figs. 6-A through 6-E)
10. K.K.	F	3 wks. (7/18/52)	5 mos. (11/21/52)	3 yrs., 10 mos.	1¾	1¾				5 yrs., 9 mos. (4/18/58)	Mild (Figs. 7-A through 7-E)
11. R.B.	M	4 wks. (11/3/54)	9 mos. (8/1/55)	2 yrs., 6 mos.	1¼					3 yrs., 10 mos. (9/26/58)	Minimal bowing; moderate genu valgum

* Epiphyseodesis of the normal tibia and fibula at the age of eleven years, seven months.

** Epiphyseodesis of the normal tibia and fibula at the age of eight years.

*** Juxta-epiphyseal insertion screws and wire at the age of two years, eight months.

FIG. 5-A

FIG. 5-B

Fig. 5-A: Case 8, D.H., July 20, 1951, at the age of four weeks. There was severe posteromedial angulation of the right tibia and fibula.

Fig. 5-B: September 19, 1952, at the age of fifteen months. There was one-half of an inch shortening.

Fig. 5-C: February 18, 1955, at the age of three and one-half years. There was considerable improvement.

FIG. 5-C

before the child began to stand—and was worn during the day until the bowing of the tibia had been well corrected by growth, the calcaneus deformity eliminated by the relief from contracture, and the appearance of strength in the triceps surae. It was changed, when necessary, to accommodate the growth of the leg. The brace consists of a double upright extending from the heel of the shoe to the hip. A laced leather cuff, or a doubled-back leather support between the rigid uprights, exerts force in an anterior direction against the tibia at the convexity of the curve, and a stop-joint at the ankle prevents calcaneus (Fig. 1). It was found to be impractical to provide a joint at the knee in the very young children. Later, as they grew older, a free joint was provided at the knee.

The ages of the patients at the time the brace was applied and removed are recorded in Table I. The length of time the brace was worn depended upon the severity of the original deformity and the rapidity of correction. This varied from one year to five years; the average was three years.

We are not fully convinced that such a brace is necessary, but we believe it is beneficial in correcting the deformity. Growing bone is pliant. The brace exerts a continual pressure or bending force directed toward straightening the tibia, and during the early years of walking lessens the deforming force of a backward thrust at the apex of the curve. It was not applied to protect the tibia from fracture. We have not feared fracture with the complications encountered in the children in Group I with anterior bowing.

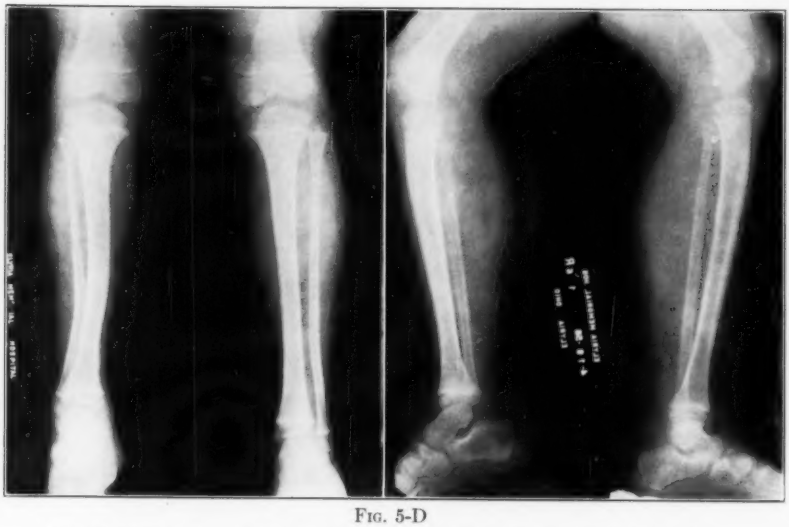


FIG. 5-D

April 18, 1958, at the age of six years and nine months. There was slight bowing.

FIG. 5-E

Photographs made April 18, 1958. The leg was straight. There was three-quarters of an inch shortening.

Other data during the course of treatment and the results are also recorded in Table I. All patients have been kept under observation, with roentgenograms from time to time, from infancy to the time of writing. Patients 1, 2, and 4 are those reported in 1949 (Figs. 2-A through 3-E). All angulations were posteromedial; none was posterolateral. *Café au lait* spots were looked for in all but none was found.

The angulation or bowing of the leg has been completely corrected, or is present to only a slight degree, in all patients. Moderate genu valgum, caused by a poorly fitting brace, developed in one patient. Rapid improvement was shown after use of the brace was discontinued. Calcaneus deformity was completely corrected in all patients, and there is no demonstrable weakness of the triceps surae muscles. The feet remain from one to two shoe sizes smaller than the normal feet. The circumference of the legs remains somewhat smaller than that of the normal

FIG. 6-A

Case 9, J.H., October 12, 1951, when four weeks old. Patient of Dr. Edward Bauman.

FIG. 6-B

June 1, 1953. Both legs at the age of one year and nine months.

legs. There is no measurable shortening of the femora, and no difference in the circumference of the thighs. The increased density of bone at the concavity of the curve gradually decreased with straightening of the bone, and eventually disappeared.

The amount of shortening was recorded at intervals during growth, beginning when the patients were three years of age and continuing to the time of writing. Our records on the amount of shortening during early infancy are not accurate. In conformity with observations in all patients that there is no appreciable ab-

FIG. 6-C

FIG. 6-D

Fig. 6-C: May 3, 1955, at the age of three years and eight months. Screws and wire mesh had been inserted immediately below the epiphyseal plates by Dr. Bauman on June 1, 1954. One year later they were removed and inserted again close to the epiphyseal plates. Shortening was still one and one-quarter inches.

Fig. 6-D: March 14, 1958, at the age of six and one half years. Shortening below the knee was one and three-eighths inches. The screws and wire mesh had remained in place for two years. There was no appreciable stimulation in growth of the length of the tibia or fibula.

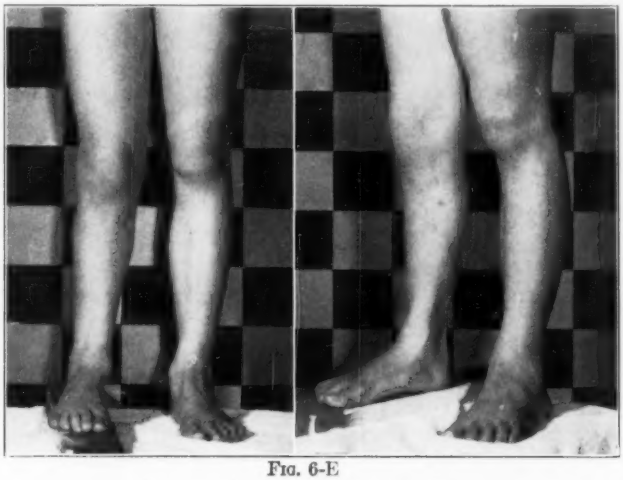


FIG. 6-E

Photographs made on March 14, 1958.

normality in the roentgenographic appearance of the upper or lower tibial epiphysis, measurements show little increase in leg-length discrepancy during growth. The maximal increase in leg-length discrepancy over that originally present is one-half of an inch. Shortening now ranges from a minimum of one-half of an inch in Patient 2, who had epiphyseodesis of the normal tibia and fibula at eight years of age, to a maximum of two inches.

With the additional experience gained from the eight cases reported here (a

FIG. 7-A

FIG. 7-B

Fig. 7-A: Case 10, K.K., August 1, 1952, when six weeks old. There was severe posterior and medial angulation and severe talipes calcaneus.

Fig. 7-B: June 18, 1954, at the age of two years. Marked improvement was evident. There was one and three-quarters inches shortening.

FIG. 7-C

FIG. 7-D

Fig. 7-C: August 17, 1956, at four years of age.

Fig. 7-D: April 18, 1958, at five years and nine months of age.

total of eleven cases), we feel no need to modify or amend the enumeration made in 1949 of the characteristics of congenital posterior angulation of the tibia, except that a dimple in the skin over the apex of the deformity has not been observed in every case. Dimples are present in many different congenital deformities of the extremities, and should not be characterized as peculiar to congenital posterior bowing of the tibia or an invariable characteristic of this deformity. All the other characteristics were manifest in every case, making this condition clearly distinguishable as an entity without confusing it with other forms of congenital bowing. Differences in one patient from another were in degree only. No abnormality

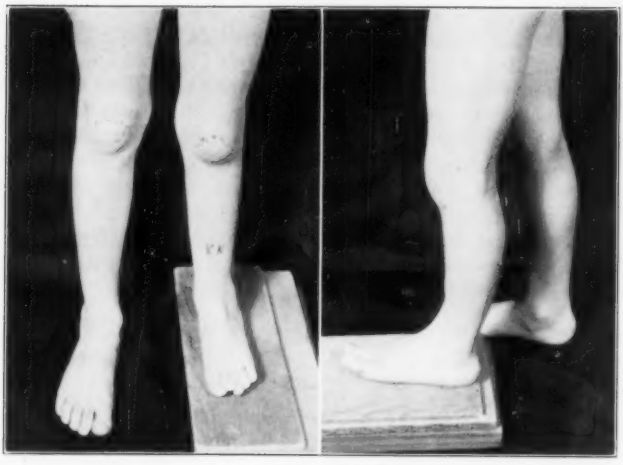


FIG. 7-E

Photographs made April 18, 1958. There was no increase in shortening which measured one and three-quarters inches.

above the knee was found in any patient, nor were there any other congenital abnormalities. All deformities were unilateral. Eight patients were boys; the other three, girls. The outstanding clinical feature of these cases is a good prognosis accompanying conservative treatment, in spite of the alarming early deformity. This at once contrasts congenital posterior bowing with the congenital anterior bowings.

Attention is directed to Patients 1 and 2. Patient 2 had epiphyseodesis performed for arrest of growth at the upper tibial and fibular epiphyses of the normal leg at the age of eight years. At that time shortening was one and one-half inches. She is now almost seventeen years old, and has only one-half of an inch leg-length discrepancy (Fig. 3-E). Patient 1 had epiphyseodesis performed when she was eleven years and seven months old, when there was one and three-quarters inches shortening. She is now eighteen years old, and still has one and one-half inches leg-length discrepancy. Epiphyseodesis was delayed too long for any significant benefit. The moderate genu varum at the normal extremity is the result of an asymmetrical fusion of the upper tibial epiphysis following epiphyseodesis.

Attention is also directed to Patient 9. On June 1, 1954, when the child was two and one-half years old, Dr. Edward Bauman attempted to stimulate growth at the upper tibial and fibular epiphyses by "curettage and drilling and insertion of S Mo screws and bone wire" immediately below the epiphyseal plates. At that time there was one and one-quarter inches shortening. On May 31, 1955, a subsequent operation was done to remove the screws and wire mesh and insert them again close to the epiphyseal plates. The screws and wire mesh were removed one year later, after being in place two years. Current roentgenographic measurements of the lengths of both tibiae show no appreciable lessening of leg-length discrepancy. There is still one and three-eighths inches shortening at the age of seven years.

These three cases are examples which explain our feelings concerning operative methods at lessening leg-length discrepancy below the knee in growing children. When the amount of shortening is sufficient to justify possible complications, we recommend epiphyseodesis of the upper tibial and fibular epiphyses of the normal leg at the optimum age—between eight and ten years old, depending upon the amount of shortening present at that time. As a result of both clinical and labora-

tory experiments, we do not recommend attempts to stimulate growth of the short tibia by the juxta-epiphyseal introduction of metals.

Even though some have reported a good result after osteotomy for correction of the deformity, we still advocate conservative treatment. Perhaps we should not have asserted so positively in our original report that osteotomy should never be done because of the likelihood of pseudarthrosis, but we still maintain that complications are always to be feared after osteotomy for correction of any congenital angulation of the tibia. Considering the facts that osteotomy was not necessary for correction of the deformity in any of the eleven patients under our observation, and there is no residual disability other than some shortening below the knee following conservative treatment, we cannot approve of osteotomy as the treatment of choice. Prognosis is good without assuming unnecessary risks.

REFERENCES

1. Badgley, C. E.; O'Connor, S. J.; and Kudner, D. F.: Congenital Kyphoscoliotic Tibia. J. Bone and Joint Surg., **34-A:** 349-371, Apr. 1952.
2. Bechtol, C. O., and Mossman, H. W.: Club-Foot. An Embryological Study of Associated Muscle Abnormalities. J. Bone and Joint Surg., **32-A:** 827-838, Oct. 1950.
3. Broca, André: Chirurgie Infantile, pp. 681-682. Paris, G. Steinheil, 1914.
4. Browne, Denis: Congenital Deformities of Mechanical Origin. Proc. Roy. Soc. Med., **29:** 1409-1431, 1936.
5. Corsi, Giuseppe: Tibie Curve Congenite. Chir. Org. Movimento, **25:** 85-100, 1939.
6. Dawson, G. R., Jr.: Intra-Uterine Fractures of the Tibia and Fibula. Report of a Case with Correction by Osteotomy and Plating. J. Bone and Joint Surg., **31-A:** 406-408, Apr. 1949.
7. Debrunner, Hans: Zur natürlichen Aufrichtung verbogner Knochen (Kasuistik). Archiv. Orthop. u. Unfall-Chir., **32:** 512-514, 1933.
8. Diaz Bordeau, E.: Tibia Curva Congénita. Arch. Hosp. Ninos Roberto del Rio, **11:** 232-236, 1943.
9. Exner, Gerhard: Zur Klinik und Pathogenese der angeborner Verbiegungen und Pseudarthrosen des Unterschenkels. Zeitschr. Orthop., **82:** 50-87, 1952.
10. Freund, Ernst: Congenital Defects of Femur, Fibula and Tibia. Arch. Surg., **33:** 349-391, 1936.
11. Froelich, M.: Traitement des Pseudarthroses Congénitales. Rev. d'Orthop., **1:** 1-19, 1910.
12. Heyman, C. H., and Herndon, C. H.: Congenital Posterior Angulation of the Tibia. J. Bone and Joint Surg., **31-A:** 571-580, July 1949.
13. Krida, Arthur: Congenital Posterior Angulation of the Tibia. A Clinical Entity Unrelated to Congenital Pseudarthrosis. Am. J. Surg., **82:** 98-102, 1951.
14. Madsen, E. T.: Fractures of the Extremities in the Newborn. Acta Obstet. Gynec. Scandinavica, **34:** 41-74, 1955.
15. Madsen, E. T.: Congenital Angulations and Fractures of the Extremities. Acta Orthop. Scandinavica, **25:** 242-280, 1956.
16. McFarland, Bryan: Pseudarthrosis of the Tibia in Childhood. J. Bone and Joint Surg., **33-B:** 36-46, Feb. 1951.
17. Miller, B. F.: Congenital Posterior Bowing of the Tibia with Talipes Calcaneo-valgus. J. Bone and Joint Surg., **33-B:** 50-55, Feb. 1951.
18. Rabinowitz, M. S.: Congenital Curvature of the Tibia. Bull. Hosp. Joint Dis., **12:** 63-74, 1951.
19. Rocher, H. L.: Trois observations de courbure congénitale de la jambe à concavite antériéure. Bull. et Mém. Soc. Nat. Chir., **53:** 1318-1323, 1927.
20. Smith, R. R.: Intra-Uterine Fracture. Report of a Case and a Review of the Literature. Surg., Gynec., and Obstet., **17:** 346-356, 1913.
21. Tilleir, R.: Courbures et pseudarthroses congénitales de la jambe. Rev. d'Orthop., **15:** 97-116, 1928.
22. Traite de Chirurgie Orthopédique. Edited by Louis Ombrédanne and P. Mathieu. Vol. V, pp. 800-816. Paris, Masson et Cie., 1937.

Dislocations of the Shoulder with Special Reference to Accompanying Small Fractures

BY RICHARD H. HALL, M.D., FRANK ISAAC, M.D.*, AND CHARLES R. BOOTH, M.D.,
LONG BEACH, CALIFORNIA

From the Orthopaedic Section of the Surgical Service and the Radiological Service, United States Veterans Administration Hospital, Long Beach

Although repeatedly reported in textbooks and journals since first discussed in 1831 [25], defects of the head and neck of the humerus related to dislocated shoulders are still being overlooked by many surgeons for at least three reasons. The defects are not demonstrated on conventional routine roentgenograms [1,8,12,20], they

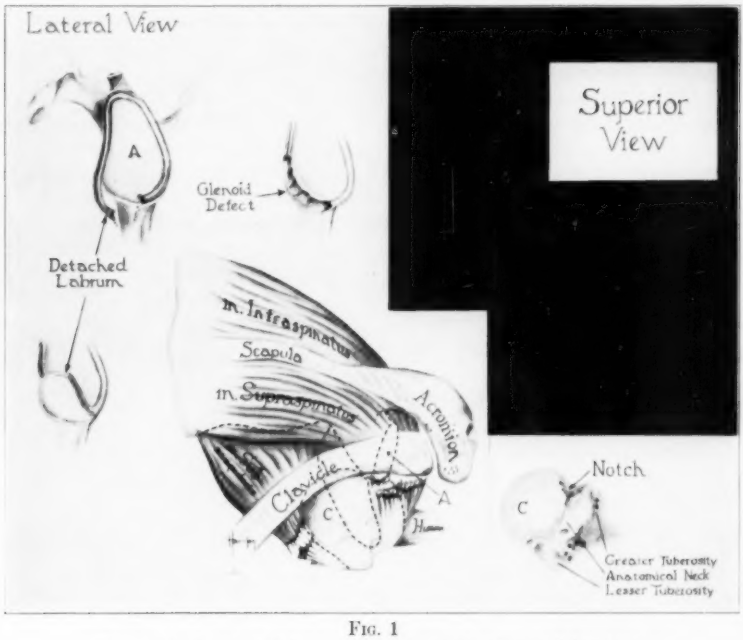


FIG. 1

Composite drawing of damaged structures in anterior dislocations.

are not readily exposed by usual anterior surgical approaches [8,16], and the clinical significance of these defects has largely been minimized or denied [8,12,20,23]. We hope to arouse attention to this aspect of the pathology created by dislocation.

Opinion has been fairly consistent regarding the essential structures injured in anterior glenohumeral dislocations [1,4,5,7,8,9,10,16,24]. Anteriorly, soft-tissue involvement consists of rupture of the articular capsule at any point, usually the area near the attachment to the glenoidal labrum (Fig. 1). The attached and overlying subscapularis is necessarily damaged to some degree. When the medial portion of the capsule is torn, the glenoidal labrum may be detached or damaged. There may be an avulsion or chip fracture of the humerus or the rim of the glenoid cavity accompanying detachment of either end of the capsule. The rim of the glenoid cavity

* Deceased.

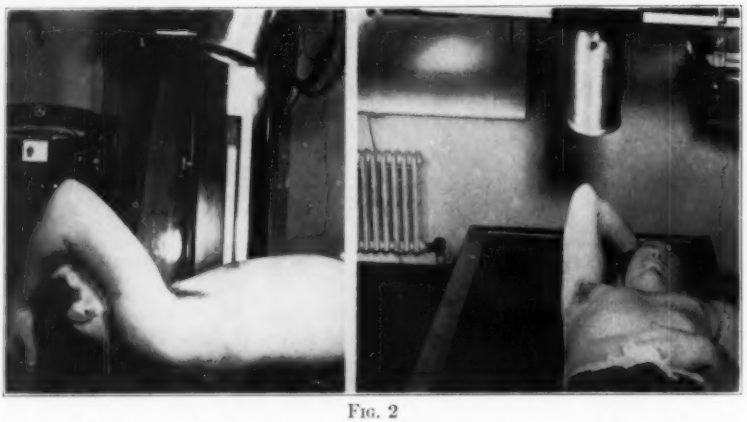


FIG. 2

Position of patient and tube for making notch-view roentgenogram of the humerus.

is most often affected. Although fractures occur at the humeral end of the articular capsule [4,16], we have been unable to find any record of their incidence.

Soft-tissue damage is often less severe posteriorly than anteriorly. It is similar in nature, but located diametrically opposite to the anterior injury [4,10,16]. The capsule may rupture at any point, usually in the area near the humerus (Fig. 1). The attached and overlying short external rotators are inevitably damaged to some degree [8,16]. When avulsion, compression or chip fracture occurs, it is usually of the humerus [4,10,16]. We have been unable to find any report of fractures of the posterior glenoidal margin, although such injuries no doubt occur. The tissues damaged by posterior dislocation are those affected by anterior dislocation; however, fractures of the humerus usually occur in front, and those of the rim of the glenoid in back [16].

It is generally agreed that any permanent disruption of the smooth gliding contours of the chondrosynovial joint surfaces may give the patient a sensation of dislocation. This sensation may spring from some minor derangement such as a ruptured labral meniscus, or a loose body, or from a true acute, chronic, or recurrent dislocation. It may also be associated with a defect of the humeral head which slips over the glenoid margin. The larger the defect in the humeral head, the less complete is the sphere formed by the humeral head and the more readily can redislocation occur.

The extent of the damage must be determined as accurately as possible. Obviously, for patients with acute dislocations, immobilization for a few weeks is necessary if the soft-tissue injuries are to heal properly. Several weeks or even a few months of immobilization may be necessary for a fracture to heal. A Putti-Platt [18], Matti, Magnuson, or related soft-tissue repair may be adequate for an anterior recurrent dislocation which has only residual soft-tissue damage. However, in cases of damaged meniscus or fractured glenoidal margin it seems more logical to consider a Bankart, Moseley, Gallie, or similar glenoidal repair. When a large notch remains on the anatomical neck, posteriorly, we prefer to do a diametrically opposite capsular repair on the back of the humeral head [13,23], reattaching the capsule to the articular margin of the humerus to fill the defect and give a smooth chondrosynovial surface. Should this same notch be found anteriorly in a posterior recurrent dislocation, similar reasoning would dictate appropriate repair.

Because demonstration of an avulsion fracture of the anatomical neck of the humerus seems important, both in the treatment of acute dislocations to help prevent recurrence and in the planning of surgical reconstitution of the damaged

joint surfaces, we feel it is highly desirable to visualize the area roentgenographically. Since the damage is seldom, if ever, demonstrated in routine anteroposterior shoulder films, we have devised a simple technique for putting this area into profile.

The patient is placed in the supine position on the x-ray table with the base of his hand centered on the top of his head (Fig. 2). The long axis of the shaft of the humerus must be parallel with the sagittal plane of the body. The shoulder is then flexed slightly beyond 90 degrees with slight internal rotation. The x-ray tube is tilted 10 degrees toward the head of the table with the beam centered on the coracoid process.

We suggest that the roentgenogram obtained in this manner be called a notch view *. It demonstrates in profile the posterosuperior and antero-inferior regions of the articular surface and anatomical neck of the humerus. Compression or avulsion fractures following strains, sprains, or dislocations of the shoulder joint most frequently occur in these two areas. Therefore, this notch view should be obtained after acute injuries of the shoulder, particularly dislocation. It can be made immediately after reduction of the dislocation with the patient anaesthetized.

It should be added, however, that this view does not obviate a tangential, inferosuperior projection of the glenoid to demonstrate possible marginal fractures.

We have made a notch-view roentgenogram of almost every patient with shoulder dislocation examined during the past four and one-half years and were able to demonstrate a posterior defect in the humeral head in eighteen of twenty patients with recurrent anterior dislocation confirmed at surgery. We were also able to demonstrate a small fracture in this area in three patients with acute an-

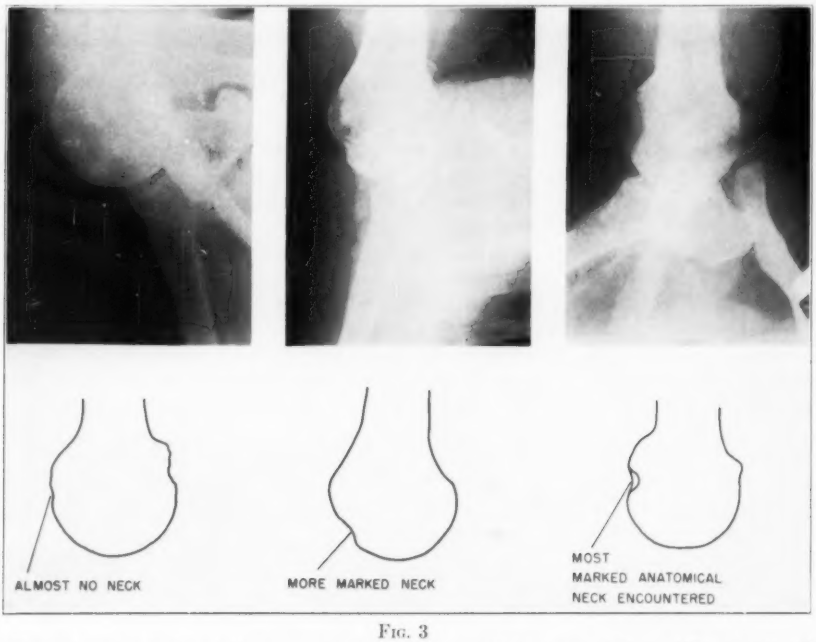


FIG. 3

Normal anatomical variations seen in notch-view roentgenograms of three different normal shoulders.

* The exact technique for the notch view was devised by the authors from ideas expressed by Commander William S. Stryker, Medical Corps, United States Navy, and associates at the United States Naval Hospital, Corona, California, in 1953. All persons concerned wish to avoid eponymous designation.

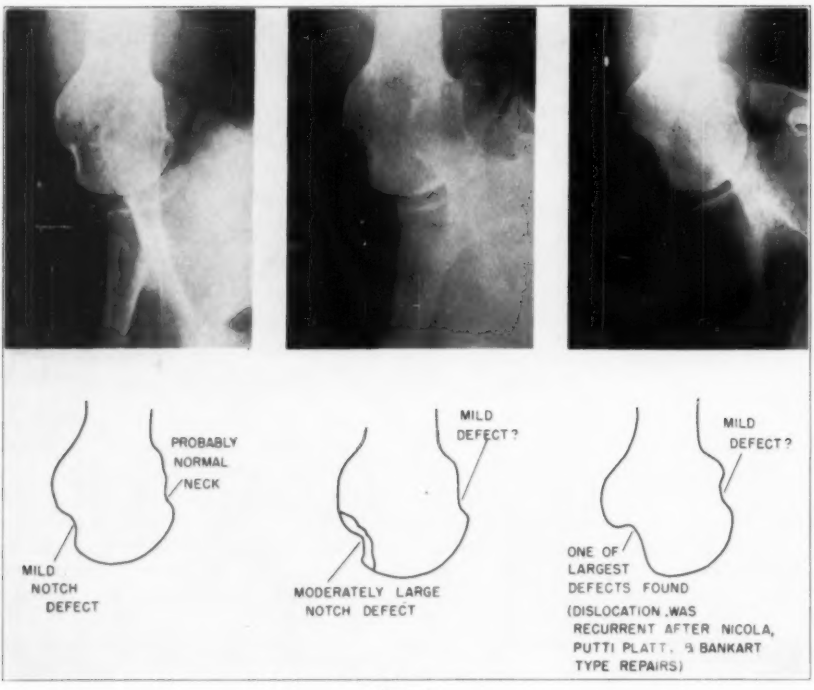


FIG. 4

Bone-contour defects seen in notch-view roentgenograms of three different patients with anterior recurrent dislocation.

terior dislocation and a large defect in two patients with chronic anterior dislocation, one confirmed at surgery. Healing of fractures was shown after immobilization in three patients with acute dislocation, with no recurrent dislocation. We have had no cases of posterior dislocations.

For a comparative study of the appearance of the normal humeral head and anatomical neck by this projection, we made notch-view roentgenograms of the shoulders of more than fifty adults with no known injuries. We did not find a typical, asymmetrical flattened notch or groove defect in any of these films, confirming Townley's extensive report on 200 non-dislocating shoulders [24]. We observed, however, that the anatomical neck exhibits considerable variations in its depth. In Morris' Human Anatomy, the anatomical neck is described as a somewhat constricted portion of bone below the head, ". . . best marked superiorly, where it forms a groove separating the articular surface from the two tubercles." It is possible, therefore, for one unfamiliar with the topographical details and normal variation of this view, to confuse a deep anatomical neck with the pathological groove defect seen in recurrent dislocation.

Roentgenographically, the uninjured anatomical neck in the notch view (Fig. 3) appears as a fairly symmetrical V or U-shaped groove with a smooth contour. This symmetry is usually lost or the smooth contour roughened by injury (Fig. 4). Both changes may occur. Although our series of cases is rather small, it gives additional support to the overwhelming evidence that the typical notch defect is generally the result of either acute or recurrent trauma or both [1,4-14,16-22]. If a sufficiently large number of such defects and fractures of the glenoid margin are recorded, it is conceivable that we may be able to predict which dislocations, if any, should be subjected to primary reparative surgery to prevent recurrence.

Perhaps, as suspected by Hippocrates [3], failure to diagnose and treat adequately such first dislocations may some day be regarded as inadequate therapy.

SUMMARY AND CONCLUSIONS

1. A defect in the posterosuperior area of the anatomical neck of the humerus was demonstrated roentgenographically in patients with acute anterior dislocation and both by roentgenograms and at surgery in patients with recurrent anterior dislocations.

2. This defect can rarely be seen on conventional, routine roentgenograms of the shoulder; at times it can be demonstrated in an uncertain degree of internal rotation. It can easily be seen in the simple roentgenographic projection described.

3. Since this defect, if large, may facilitate recurrent dislocation, it should be looked for in all acute injuries. If it can be accomplished by adequate immobilization, this defect should be allowed to heal and fill in.

4. In recurrent dislocation of the shoulder the defect should be evaluated when planning surgical repair. It is the author's opinion that the defect, if large, should be repaired just as the labral defect is repaired anteriorly.

5. The defect, usually traumatic in origin, should not be confused with normal anatomical variations.

REFERENCES

1. Adams, J. C.: Recurrent Dislocation of the Shoulder. J. Bone and Joint Surg., **30-B:** 26-38, Feb. 1948.
2. Bankart, A. S. B.: The Pathology and Treatment of Recurrent Dislocation of the Shoulder Joint. British J. Surg., **26:** 23-29, 1938.
3. Bick, E. M.: Source Book of Orthopaedics, pp. 369-374. Baltimore, The Williams and Wilkins Co., 1948.
4. Bost, F. C., and Inman, V. T.: The Pathological Changes in Recurrent Dislocation of the Shoulder. A Report of Bankart's Operative Procedure. J. Bone and Joint Surg., **24:** 595-613, July 1942.
5. Broca, A., and Hartmann, H.: Contribution à l'étude des luxations de l'épaule (luxations dites incompletes décollements périostiques, luxations directes at luxations indirectes). Bull. de la Société Anat. de Paris, **65:** 312, 1890.
6. Cave, E. F., and Rowe, C. R.: Capsular Repair for Recurrent Dislocation of Shoulder. Pathological Findings and Operation Technic. Surg. Clin. North America, **27:** 1289-1294, 1947.
7. Delbet, Pierre: Des luxations anciennes et irreducible de l'épaule. Arch. Gen. de Med., **31:** 144-163, 1893.
8. DePalma, A. F.: Surgery of the Shoulder. Philadelphia, J. B. Lippincott Co., 1950.
9. Eyre-Brook, A. L.: Recurrent Dislocation of the Shoulder. Lesions Discovered in Seventeen Cases, Surgery Employed, and Intermediate Report on Results. J. Bone and Joint Surg., **30-B:** 39-48, Feb. 1948.
10. Flower, W. H.: On the pathological changes produced in the shoulder-joint by traumatic dislocation, as derived from an examination of all the specimens illustrating this injury in the Museums of London. Trans. Pathol. Soc. London, **12:** 179-200, 1861.
11. Gallie, W. E., and LeMesurier, A. B.: Recurring Dislocation of the Shoulder. J. Bone and Joint Surg., **30-B:** 9-11, Feb. 1948.
12. Hill, H. A., and Sachs, M. D.: The Grooved Defect of the Humeral Head. A Frequently Unrecognized Complication of Dislocations of the Shoulder Joint. Radiology, **35:** 690-700, 1940.
13. MacAusland, W. R.: Recurrent Dislocation of the Shoulder with Report of Cases. Surg., Gynec., and Obstet., **38:** 739-747, 1924.
14. Matti, H.: Zur operativen Behandlung der habituellen Luxation des Schultergelenks. Zentralbl. f. Chir., **63:** 3011-3018, 1936.
15. Morris' Human Anatomy. Edited by J. Parsons Schaeffer. Ed. 10, p. 196. Philadelphia, The Blakiston Co., 1942.
16. Moseley, H. F.: Shoulder Lesions. Ed. 2. New York, Paul B. Hoeber, 1953.
17. Nicola, Toufick: Acute Anterior Dislocation of the Shoulder. J. Bone and Joint Surg., **31-A:** 153-159, Jan. 1949.
18. Osmond-Clarke, H.: Habitual Dislocation of the Shoulder. The Putti-Platt Operation. J. Bone and Joint Surg., **30-B:** 19-25, Feb. 1948.
19. Palmer, Ivar, and Widén, Anders: The Bone Block Method for Recurrent Dislocation of the Shoulder Joint. J. Bone and Joint Surg., **30-B:** 53-58, Feb. 1948.
20. Speed, Kellogg: Recurrent Anterior Dislocation of the Shoulder. Operative Cure by Bone Graft. Surg., Gynec., and Obstet., **44:** 468-477, 1927.
21. Tavernier, L.: The Recurrent Luxation of the Shoulder. *In* News Notes. J. Bone and Joint Surg., **12:** 458-461, 1930.

22. THOMAS, T. T.: Habitual or Recurrent Dislocation of the Shoulder. Eighteen Shoulders Operated on in Sixteen Patients. Surg., Gynec., and Obstet., **18**: 107-115, 1914.
23. THOMAS, T. T.: Recurrent Dislocation of the Shoulder Joint. J. Am. Med. Assn., **85**: 1202-1208, 1925.
24. TOWNLEY, C. O.: The Capsular Mechanism in Recurrent Dislocation of the Shoulder. J. Bone and Joint Surg., **32-A**: 370-380, Apr. 1950.
25. TYRRELL, FREDERICK: The Lectures of Sir Astley Cooper on the Principles and Practice of Surgery with Additional Notes and Cases. Vol. 3, pp. 195-234. Boston, Lilly and Wait, 1831.

Epiphyseal Growth Arrest in a Fractured Metacarpal

BY JOSEPH EDMUND BROWN, M.D., CLEVELAND, OHIO

From the Department of Orthopaedic Surgery, Saint Luke's Hospital, Cleveland

Injuries involving open epiphyses have always carried a guarded prognosis from the standpoint of premature closure and growth arrest. In specific instances partial closure and a resultant growth deformity can create cosmetic and functional deformity, which may well require reconstructive measures. All surgeons dealing with trauma are cognizant of the seriousness of epiphyseal injuries of major joints, particularly those involving the ankle, knee, hip, wrist, and elbow. Accordingly, when such injuries occur the parents are warned by attending surgeons of the danger of growth arrest and the patients are usually followed for considerable periods of time, until one can be assured that no complication has developed.

Metacarpal fractures in young boys are relatively common, but case reports of premature closure of the metacarpal epiphyses are not to be found in the literature. In fact, prior to the rather startling result encountered in the case to be reported, this observer gave little thought to premature closure of the epiphysis of the metacarpal due to trauma.

On February 3, 1953, a twelve-year-old boy was struck by an automobile and had multiple injuries. The least significant injury from the standpoint of immediate care was a fracture of the distal end of the left third metacarpal. This fracture by all standards was simple and undisplaced, although it involved the distal epiphyseal plate (Fig. 1).

No specific treatment was directed toward this simple fracture; and at the time of the boy's dismissal from active medical care, four months after the injury, he had no complaints referable to the left hand. It is to be noted in Figure 1 that the lengths of the fingers are in normal proportion, namely, the long finger longer than the adjacent index and ring fingers.

On December 8, 1956, the boy injured his right hand playing basketball. This injury was of no clinical significance, but upon examination of the boy's hands, I was amazed to observe that the left long finger was considerably shorter than the adjacent index and ring fingers.

FIG. 1

FIG. 2

Fig. 1: Roentgenographic appearance of the fracture of the left third metacarpal at the time of injury.

Fig. 2: Roentgenogram made almost four years after the injury. Note the premature closure of the epiphysis of the left third metacarpal.

FIG. 3

Roentgenographic appearance of hands approximately six years after injury when the patient was eighteen.

A roentgenogram (Fig. 2) made at this time revealed a premature closure of the distal epiphysis of the left third metacarpal and shortening of the long finger. The boy had no functional disability referable to the short long finger, but readily admitted that it was an "oddity."

On November 21, 1958, the patient, now seventeen years old, was re-examined (Figs. 3 and 4). The left long finger was found to be one inch shorter than its counterpart of the right hand. There was still no functional disability present in spite of the fact that with the fist clenched (Fig. 5) a marked deformity was evident with alteration of the metacarpophalangeal joint relationships.

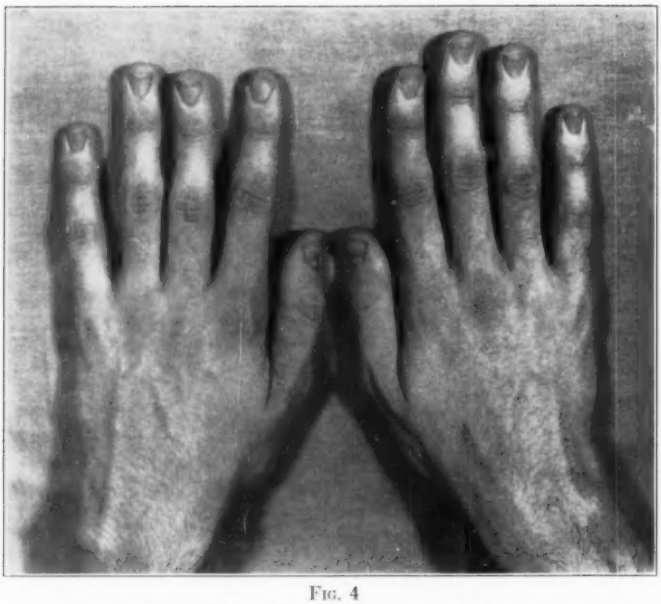


FIG. 4

Appearance of the hands when the patient was eighteen years old. The left long finger is an inch shorter than the right long finger.

FIG. 5

The clenched fist accentuates the deformity. There is no functional deficit.

CONCLUSION

Considering the high incidence of trauma to the adult hand and the resultant large numbers of roentgenograms of adult hands, one would expect that if premature closure of the metacarpal epiphysis was a frequent occurrence as a result of injury to the hand in childhood, roentgenologists would be in a position to cite many case examples similar to the one reported here. A survey of leading roentgenologists in the Cleveland area failed to uncover a similar case.

Because of the apparent rarity of this condition, it is felt that this case report may prove of interest to surgeons dealing with trauma, and that it may spare them the embarrassment of explaining a "short finger" at a later date.

Partial and Complete Agenesis or Malformation of the Sacrum With Associated Anomalies

Etiologic and Clinical Study with Special Reference to Heredity
A Preliminary Report

BY JOHANNA BLUMEL, PH.D., E. BURKE EVANS, M.D.,
AND G. W. N. EGGERS, M.D., GALVESTON, TEXAS

From the Division of Orthopaedics, Department of Surgery, University of Texas Medical Branch, Galveston

Sporadic case reports of congenital sacral and coccygeal agenesis and eight cases of these anomalies now under observation at John Sealy Hospital prompted us to initiate this investigation.

A review of the literature [1,2,4-10,12-15,18-29,31,33-41,43-60,62-66] revealed that approximately fifty cases have been reported since Hohl described the condition in 1852 and Wertheim reported a case of complete sacrococcygeal agenesis in a newborn girl in 1857. This number of published cases in more than a century by no means reflects the actual incidence of these malformations. Several etiological theories have been discussed by various authors [19,24,29,54,62], but to our knowledge no genetic studies have been attempted.

MATERIAL AND METHODS

In March 1957, survey forms were sent to 300 orthopaedic surgeons in the United States and Hawaii requesting information on congenital absence or malformation of the sacrum for statistical compilation and genetic analysis. As of May 1958, replies were received from sixty-three surgeons, twenty of whom treated one to six such patients. Thirty-six case reports were obtained in this manner. It was subsequently decided to make a survey of each state by sending forms to record librarians at the larger hospitals. One hundred Texas hospitals were written to; thirty-two replied, and four of these furnished a total of eight cases. A survey is currently being made of hospitals in other states. This is a preliminary report on fifty cases, including more extensive data on our own eight cases with special reference to manifestations of hereditary abnormalities in collaterals and ascendants.

CASE REPORTS AND PEDIGREES

In this investigation, the pedigree charts have Roman numerals on the left indicating generations and Arabic numbers identifying individuals. The following eight case histories from John Sealy Hospital are presented in the order in which they appear in Table I.

Case 1 (1-8311-M). Chart I, II-3: This white girl was born November 17, 1955. The mother had a normal full-term pregnancy and normal labor and delivery. Birth weight was five pounds, nine ounces. No anomalies were noted at birth; however, physical examination one year later revealed a slight deviation of the upper end of the natal cleft (Fig. 1-A).

Roentgenograms of the pelvis (Fig. 1-B) disclosed absence of the ala of the third sacral vertebra with approximation of the second and fourth alae on the left and a resulting shift of the more distal sacral vertebrae and the coccyx to that side. There were no other vertebral anomalies. There was no disturbance of sensation in the lower extremities and no alteration of bowel or bladder function. No treatment was necessary.

Chart I shows that the proband has two older siblings born in 1952 and 1953, respectively; both are apparently normal as are ascendants and collaterals in this

TABLE I

FIFTY CASES OF COMPLETE AND PARTIAL ABSENCE OR MALFORMATION OF THE SACRUM WITH ASSOCIATED ANOMALIES

CASE NO.	DOCTOR OR INSTITUTION SUBMITTING INFORMATION	DEFECT		COMPLICATIONS OF PREGNANCY OR DELIVERY	SEX	RACE	DATE OF BIRTH	NUMBER OF SIBLINGS	NUMBER OF ABORTIONS	VERTEBRAL DEFECTS	OTHER CONGENITAL ANOMALIES
		COMPLETE	PARTIAL								
1	Dept. of Orthopedics, John Sealy Hospital, Galveston, Texas		+	None	F	W	11-17-55	2	0	Absence of alae of S-3; approximation of S-2 and S-4 alae on left	Right inguinal hernia
2	Dr. C. A. Hooks, Dept. of Urology, John Sealy Hospital, Galveston, Texas		+	Mother is diabetic	M	W	2-17-43	4		Spina bifida occulta of L-5 and S-1; absence of spine below S-3	Bladder neck sphincter paralysis
3	Dept. of Orthopedics, John Sealy Hospital, Galveston, Texas		+	Mother is diabetic; breech delivery; birth weight —4 lbs., 5 oz.	F	N	8-27-51	2	2	Absence of L-5; absence of 2 sacral vertebrae and symmetric hypoplasia of 3 sacral vertebrae; absence of the coccyx	Bilateral club-foot; bilateral dislocation of hips; strabismus
4	Dept. of Orthopedics, John Sealy Hospital, Galveston, Texas	+		Mother ill during entire pregnancy; birth weight —5 lbs., 2 oz.	M	M	4- 4-54	10	3	Absence of spine below L-4 with mid-line approximation of ilia	Bilateral club-foot; limited knee motion with marked muscle atrophy below knees and dislocation of right hip
5	Dr. C. A. Hooks, Dept. of Urology, John Sealy Hospital, Galveston, Texas		+		F	W	1- 5-50	6	1	Absence of spine below S-3	Ureteral stricture; neurogenic urinary bladder; paralysis of external urethral sphincter
6	Dept. of Orthopedics, John Sealy Hospital, Galveston, Texas	+		Mother is diabetic	F	N	8-26-53	8	0	Absence of spine below L-3 with mid-line approximation of ilia	Umbilical hernia; bilateral club-foot; bilateral dislocation of hips and atrophy of lower extremities; cleft lip
7	Dr. C. A. Hooks, Dept. of Urology, John Sealy Hospital, Galveston, Texas		+	Mother had virus infection during 5th month of pregnancy; membranes ruptured 6 days prior to delivery with false labor	M	W	4- 2-54	1	0	Fusion of left 8th and 9th ribs at their vertebral ends; bifid T-11; an extra right hemivertebra between T-11 and T-12; L-2 and L-4 are left hemivertebrae; gross deformity of all lumbar vertebrae; absence of spine below S-3	Imperforate anus; left talipes equinovarus; right talipes calcaneovalgus; urethral stricture; absence of right kidney; recto-urethral fistula; poor development of lower extremities below knees

8	Dr. C. A. Hooks, Dept. of Urology, John Sealy Hospital, Galveston, Texas		+		F	W	4-21-09	1	2	High thoracic scoliosis associated with minor vertebral anomalies; absence of spine below S-2	Left inguinal hernia
9	Texas Scottish Rite Hospital for Crippled Children, Dallas, Texas	+			M	W	9-11-31	5		Almost complete absence of lumbar spine and sacrum	Soft tissue contractures of both knee joints
10	Texas Scottish Rite Hospital for Crippled Children, Dallas, Texas		+	None	F	W	6-14-31	2		Partial absence of the sacrum and complete absence of the coccyx	
11	Southwestern General Hospital, El Paso, Texas		+		M	W	15 years old in 1948	1		Partial absence of the sacrum and complete absence of the coccyx; spina bifida occulta	
12	Dr. A. R. Shands, Jr., Alfred I. duPont Institute, Wilmington, Delaware	+		Mother had hypertension at 7th month of pregnancy; delivery was by C-section	M	W	4- 5-52	5	0	Abnormal L-2; complete absence of spine below L-2	Arthrogryposis of lower extremities; bilateral congenital dislocation of hips; flexion contractures of knees; bilateral talipes equinovarus
13	Dr. A. R. Shands, Jr., Alfred I. duPont Institute, Wilmington, Delaware		+		M	W	3-25-50	1		Hypoplasia of S-4 and S-5; hypoplasia of the coccyx	Undescended testicle, right
14	Dr. A. R. Shands, Jr., Alfred I. duPont Institute, Wilmington, Delaware		+		M	N	2-28-51	3		2 abnormal lumbar vertebrae; absence of 3 lumbar vertebrae; complete bifid sacrum; absence of the coccyx	Bilateral cleft lip and palate; bilateral inguinal hernia; paralysis of lower extremities; bilateral club-foot
15	Dr. A. R. Shands, Jr., Alfred I. duPont Institute, Wilmington, Delaware	+			F	W	12- 7-47	2	0	Anomalies of L-1, L2, and L-3; absence of spine below L-3	Lumbar meningomyelocele; paralysis from mid-thigh down, bilaterally; bowel and bladder incontinence; equinovarus, left; anomaly of 1st rib, left
16	Dr. A. R. Shands, Jr., Alfred I. duPont Institute, Wilmington, Delaware	+			M	W	7-25-42	2	0	Anomalies of L-1 and L-2; absence of spine below L-2	Deformed pelvis; rib abnormalities; meningomyelocele
17	Dr. J. S. Barr— Dr. John F. Bell, Crippled Children's Division, Burlington, Vermont	+		Breech delivery	M	W	2-27-55	2	0	Absence of spine below L-2	Bilateral equinovarus; urinary incontinence; difficulty emptying bowels
18	Dr. A. L. Benshon, St. Vincent Hospital, Toledo, Ohio	+			F	W	April, 1953	1	0	Complete absence of sacrum and coccyx	Arthrogryposis; dislocated hips

TABLE I—*Continued*

FIFTY CASES OF COMPLETE AND PARTIAL ABSENCE OR MALFORMATION OF THE SACRUM WITH ASSOCIATED ANOMALIES

CASE NO.	DOCTOR OR INSTITUTION SUBMITTING INFORMATION	DEFECT		COMPLICATIONS OF PREGNANCY OR DELIVERY	SEX	RACE	DATE OF BIRTH	NUMBER OF SIBLINGS	NUMBER OF ABORTIONS	VERTEBRAL DEFECTS	OTHER CONGENITAL ANOMALIES
		COMPLETE	PARTIAL								
19	Dr. A. L. Benshon, St. Vincent Hospital, Toledo, Ohio	+			M	W	12-22-53			Complete absence of sacrum and coccyx	Anal stenosis; arthrogryposis multiplex congenita; bilateral club-foot
20	Dr. B. H. Curtis Newington Home and Hospital for Crippled Children, Newington 11, Connecticut		+	None	M	W	12-18-45	1	0	Defects in neural arches of lower lumbar spine; gross distortion of the sacrum with absence of lateral components on one side	Meningomyelocele; talipes equinovarus, severe; urinary incontinence
21	Dr. M. C. Cobey, Washington, D. C.	+		None	F	W	1949	1	0	Complete absence of sacrum and coccyx	Bilateral club-foot
22	Dr. Phillip L. Day, San Antonio, Texas	+			M	M	11- 3-51	4		Narrowing of lower lumbar vertebrae; complete absence of sacrum and coccyx	Congenital heart disease; atrophy of arms and legs as in arthrogryposis
23	Dr. Phillip L. Day, San Antonio, Texas	+			M	M	11-20-51	2		Absence of lower half of lumbar spine; complete absence of sacrum and coccyx; spina bifida with meningocele	Paralysis of lower extremities
24	Dr. C. H. Heyman, Cleveland, Ohio	+		None	F	W	3- 1-35			Congenital scoliosis and kyphosis of dorsolumbar region	Dislocated right hip; bilateral club-foot; flexion deformity of knees; severe; anaesthesia of both legs below knees; bladder and bowel incontinence
25	Dr. Samuel S. Mathews, Children's Hospital, Los Angeles, Calif.	+		Breech delivery	M	W	4- 5-54	1	0	Complete absence of sacrum and coccyx	Imperforate anus
26	Dr. James S. Miles, Denver General Hospital, Denver, Colorado	+		None	F	W	2-13-56	3	1	Absence of spine below L-2	Bilateral dislocation of hips; bilateral talipes equinovarus; bilateral fixed extension of knees; loss of sphincter control
27	Dr. Edward T. Smith— Dr. Bruce Clawson	+			F	M	3-28-47			Complete absence of sacrum	Deformities of feet

	Houston, Texas										
28	Dr. Frank Stinchfield, N. Y. Orthopedic Hospital, New York 32, N. Y.	+		None	F	W	7- 9-18	2	0	Three lumbar vertebrae present with a mass of bone representing the lower lumbar vertebrae; complete absence of the sacrum and coccyx	Bilateral talipes equinovarus
29	Dr. I. L. Van Zandt, Ft. Worth 4, Texas		+	None	F	W	1-14-50	1		Partial absence of sacrum and coccyx	None
30	Dr. F. Leon Ware, Dallas, Texas	+			F	W	April, 1949			Complete absence of sacrum and coccyx	Imperforate anus; rectovaginal fistula; bilateral club-foot with minimal motion in both knees
31	Dr. C. B. Larson— Dr. Robt. Lillo, Children's Hospital, State Univ. of Iowa, Iowa City, Iowa	+		Mother is diabetic	F	W	December 1939	3		Spina bifida of L-5; complete absence of sacrum and coccyx	Bilateral club-foot; paralysis and atrophy of muscles of feet and legs, especially distally
32	Dr. C. B. Larson— Dr. Robt. Lillo, Children's Hospital, State Univ. of Iowa, Iowa City, Iowa	+			M	W	1919			Spina bifida, L-4 and L-5; complete absence of sacrum and coccyx	Dislocated hips
33	Dr. C. B. Larson— Dr. Robt. Lillo, Children's Hospital, State Univ. of Iowa, Iowa City, Iowa		+		M	W	1944			Spina bifida; absence of spine below S-1	Arthrogryposis; congenital talipes calcaneovalgus, bilateral
34	Dr. C. B. Larson— Dr. Robt. Lillo, Children's Hospital, State Univ. of Iowa, Iowa City, Iowa	+		None	M	W	1949			Fusion of ribs 11 and 12 at distal portion of 12th vertebra; absence of lumbosacral spine	Very shallow acetabulae; web contractures of knees with soft tissue between thigh and leg holding knees in 70° of flexion
35	Dr. C. B. Larson— Dr. Robt. Lillo, Children's Hospital, State Univ. of Iowa, Iowa City, Iowa		+	Breech delivery	F	W	11-21-34	5	0	Right scoliosis in dorsal region due to wedging of T-3 through T-9 and a compensatory scoliosis in lumbar region with wedging of L-4 and L-5; sacrum small and deformed; absence of coccyx	Bilateral club-foot with absence of middle phalanges of all toes on left foot except first

TABLE I—*Continued*

FIFTY CASES OF COMPLETE AND PARTIAL ABSENCE OR MALFORMATION OF THE SACRUM WITH ASSOCIATED ANOMALIES

CASE NO.	DOCTOR OR INSTITUTION SUBMITTING INFORMATION	DEFECT		COMPLICATIONS OF PREGNANCY OR DELIVERY	SEX	RACE	DATE OF BIRTH	NUMBER OF SIBLINGS	NUMBER OF ABORTIONS	VERTEBRAL DEFECTS	OTHER CONGENITAL ANOMALIES
		COMPLETE	PARTIAL								
36	Dr. Walter P. Blount—Dr. R. C. Waisman, Milwaukee, Wisconsin	+		Mother is diabetic and had frequent insulin reactions during pregnancy	M	W	2- 2-51	1	0	Absence of spine below L-1	Associated congenital defect of cord with cord bowel and bladder; left strabismus at birth; rudimentary lower extremities with spotty areas of sensation and trace movements
37	Dr. G. A. Caldwell—Dr. Edw. A. Attix, Ochsner Clinic, New Orleans, La.		+	None	M	W	10-14-53	1	0	Absence of auricular ossification center on right; hypoplasia of right ilium; hemivertebra of L-5 with spina bifida of L-5 and myelomeningocele; hemivertebrae at S-1 and S-2 with absence of lateral masses	Dysplasia of right hip
38	Dr. Elias Margo, Bone and Joint Hospital, Oklahoma City, Okla.		+	None	M	W	1933			Congenital scoliosis of lumbar vertebrae; partial absence of sacrum; absence of the coccyx	
39	Dr. H. A. Sofield, Shriners' Hospital for Crippled Children, Chicago, Illinois	+		None	F	W	4-11-46	3	0	Absence of spine below T-12	Contractures of lower extremities and equinovarus of feet
40	Dr. H. A. Sofield, Shriners' Hospital for Crippled Children, Chicago, Illinois	+		None	F	W	7- 4-57	0	0	Absence of spine below L-2	
41	Dr. H. A. Sofield, Shriners' Hospital for Crippled Children, Chicago, Illinois		+	Mother had vaginal bleeding during 8th month; labor lasted 3 days; breech delivery	M	W	9-28-43	2	1	Congenital fusion of cervical vertebrae; scoliosis of dorsolumbar spine and anomalies of bodies of dorsal and lumbar spine	Congenital synostosis, talus and calcaneus; coxa vara of right hip; arthrogryposis multiplex congenita of all 4 extremities
42	Dr. H. A. Sofield, Shriners' Hospital for Crippled Children, Chicago, Illinois	+		10-month pregnancy; few fetal movements; 30-hour labor; breech delivery	M	W	8-13-53	1	0	Multiple anomalies in cervical region; spine absent below L-1	Congenital coxa vara, bilaterally

	Shriners' Hospital for Crippled Children, Chicago, Illinois			hour labor; breech delivery; mother is diabetic							congenita; congenital dislocation of hips; bilateral talipes equinovarus
44	Dr. H. A. Sofield, Shriners' Hospital for Crippled Children, Chicago, Illinois	+		Breech delivery	F	W	8-25-53	2	0	Absence of spine below L-2	Flexion contractures of both hips and knees; bilateral equinovarus
45	The Children's Mercy Hospital, Kansas City, Missouri		+	Mother had "flu" at 2nd or 3rd month of gestation	M	W	10- 8-56	3	0	Hemivertebrae at T-3; agenesis of left sacral wing with malformation of right sacral wing	Reduplication of colon, penis, and bladder; congenital heart disease; rectourethral fistula; microcephaly; anophthalmos, O.S.; ankylosis of mandible to maxilla; cleft palate; imperforate anus
46	The Children's Mercy Hospital, Kansas City, Missouri	+		None	F	W	4-20-41	4		Maldevelopment of L-2 and L-3; absence of spine below L-3	Club-foot; flexion deformity of knees and hips; left ankle and foot fused in dorsiflexion; bilateral absence of fibula; dislocation of right hip; urinary incontinence
47	Dr. Don King— Dr. D. K. Clawson, Stanford Univ. Hospital, San Francisco 15, Calif.	+		Birth weight—4 lbs., 13 oz.	F					Complete absence of sacrum and coccyx	Tightness of all joints in lower extremities; absence of all normal skin folds; bladder and bowel incontinence; flexion deformity of both hips (45°); bilateral club-foot
48	Dr. Don King— Dr. D. K. Clawson, Stanford Univ. Hospital, San Francisco 15, Calif.	+		1 month overdue at time of delivery	M			3	0	Complete absence of sacrum and coccyx	Bilateral equinovarus
49	Dr. T. C. Thompson— Dr. P. J. Marchisello, Hospital for Special Surg., New York, N. Y.	+		Mother is diabetic	M	W	1-29-44	2		Only 3 lumbar vertebrae present with distorted 4th segment between ilia; spina bifida at L-3; complete absence of sacrum and coccyx	Bilateral equinovarus
50	Dr. T. C. Thompson— Dr. P. J. Marchisello, Hospital for Special Surg., New York, N. Y.	+		Breech delivery	M	W	4-23-46	5		2 hemivertebrae at T-3 and T-6; 10 complete thoracic vertebrae; 10 ribs on left and 12 on right; gross distortion of lower 3 lumbar segments; complete absence of sacrum and coccyx	Equinovarus on left; calcaneovalgus on right

FIG. 1-A

FIG. 1-B

Fig. 1-A: Photograph showing slight deviation of the upper end of the natal cleft.
Fig. 1-B: Roentgenogram of the pelvis showing absence of the alae of the third sacral vertebra with approximation of the second and fourth alae on the left.

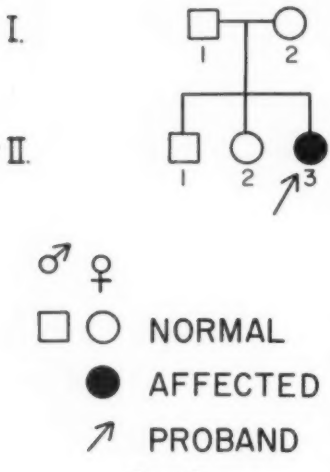


CHART I
Case 1.

pedigree. The presence of a right inguinal hernia was established by correspondence with the proband's father, who is a physician.

CASE 2 (28141-M). Chart II, III-6: This white boy was born February 17, 1943. He was admitted to the Urology Service at John Sealy Hospital on July 20, 1956, because of bowel and bladder incontinence which had been present since birth. His general physical examination revealed a healthy, well developed, thirteen-year-old boy with no apparent abnormalities.

Roentgenograms (Fig. 2) of the pelvis demonstrated spina bifida occulta of the first sacral vertebra and absence of the distal two sacral vertebrae and the coccyx. A myelogram revealed termination of the dural sac at the fifth lumbar vertebra. A cystogram showed trabeculation of the bladder but no ureteral reflux. An intravenous pyelogram demonstrated normal upper urinary tracts. Cystoscopic examination revealed moderate bladder trabeculation but no obstruction of the neck of the bladder. The external sphincter was patulous; otherwise, the urethra was normal.

Neurosurgical exploration of the lumbosacral region revealed normal nerve roots at the fourth lumbar-fifth lumbar level but at the fifth lumbar-first sacral level there emerged three relatively larger roots of which one proceeded laterally on each side at this level and one proceeded distally into the sacral canal. A cystometrogram was made while cord and nerve roots were exposed. With electrical stimulation it was found that the vesical reflex arc was intact, bladder response occurring with stimulation. Urological procedure consisted in vesical neck revision and bulbo-urethral plication. Training in urinary control is still in progress at the time of writing.

An interview with the proband (Chart II) and his father (II-2) in August 1956 revealed that the mother (II-1) had diabetes and died in June 1956 at the age of fifty-two of cardiac failure. She had had diabetes mellitus fifteen years prior to her death. The father has arthritis and high blood pressure. No accurate information is available as to the mother's length of gestation, character of labor, or type of delivery. However, according to our informants, there

FIG. 2

Case 2. Roentgenogram of the pelvis showing spina bifida occulta of the first sacral vertebra and absence of the distal two sacral vertebrae and the coccyx.

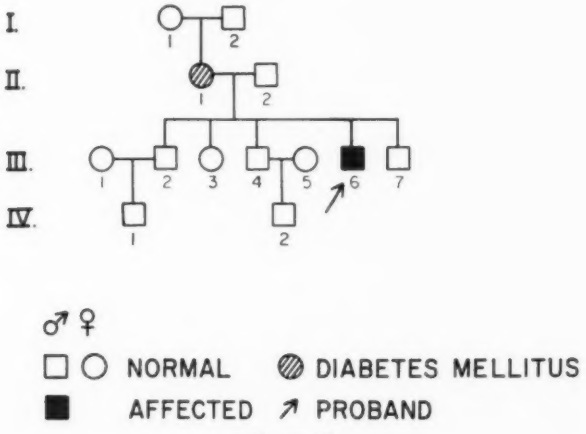


CHART II

Case 2.

was no trauma associated with the birth of the proband. In 1952, the family was told by a roentgenologist that the patient "had no tail-bone" and that "nothing could be done about his incontinence." Careful questioning did not reveal any additional abnormalities in members of this pedigree. Roentgenograms showed the spine and pelvis of the proband's father (II-2) to be normal.

FIG. 3-A

FIG. 3-B

Case 3. Photographs taken at age five and six years, respectively, showing atrophy of the lower extremities below the knees; flexion contracture of the right knee; residual foot deformity, bilaterally; and flattening of the buttocks with lumbar kyphosis.

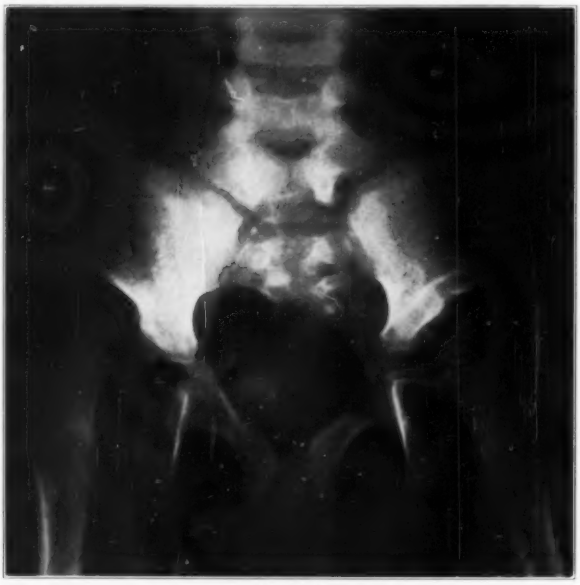


FIG. 3-C

Roentgenogram of the pelvis showing absence of the fifth lumbar vertebra; absence of two sacral vertebrae with symmetric hypoplasia of the remaining sacral vertebrae; absence of the coccyx; articulation of the fourth lumbar vertebra with the ilium on the right; dislocation of the left femoral head into the iliac fossa; and subluxation of the right femoral head.

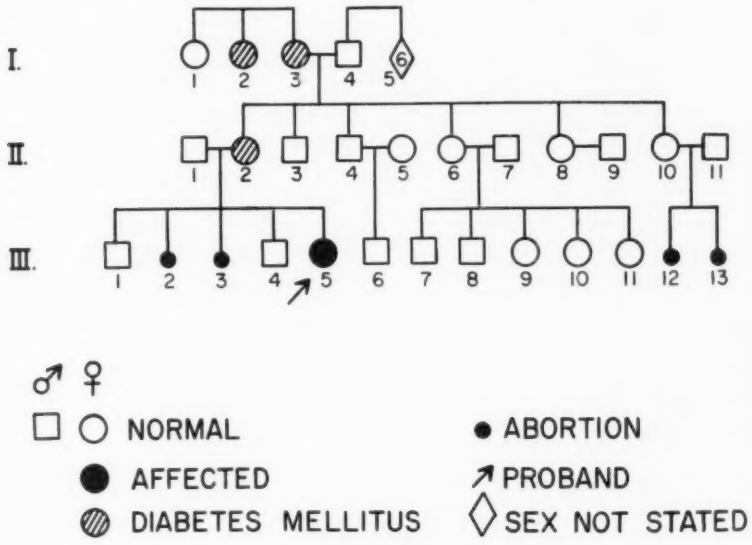


CHART III

Case 3.

CASE 3 (H-137-94). Chart III, III-5: This Negro girl was born August 27, 1951. Delivery by breech presentation followed the mother's full-term pregnancy. Birth weight was four pounds, five ounces. The mother had diabetes mellitus which apparently was well controlled during this pregnancy. Insulin therapy was begun in 1947. A few days after the proband's birth, it was noted that the infant's feet were turned in and she was admitted to John Sealy Hospital on December 3, 1951, for evaluation.

Physical examination at that time, and subsequently, revealed the following anomalies: microcephaly, convergent strabismus (diagnosed as an alternating esotropia), marked atrophy of the lower extremities below the knees with limitation of motion at the knees, bilateral resistant talipes equinovarus, dislocation of the left femoral head, and a flattening of the buttocks with lumbar kyphosis (Figs. 3-A and 3-B).

Roentgenograms of the pelvis (Fig. 3-C) made when the child was five years old revealed the following anomalies: absence of the fifth lumbar vertebra with articulation of the fourth lumbar to the ilium, only three readily identifiable sacral vertebrae all showing symmetrical hypoplasia, absence of the coccyx, dislocation of the left femoral head into the iliac fossa, and subluxation of the right femoral head. Treatment consisted in manipulation and plaster correction of the feet with poor but functional results, surgical construction of a shelf for the left acetabulum, and Achilles tenotomy on the right leg, the correction thus obtained being held with a brace. The patient now walks independently. She has impaired muscle function but good sensation below the knees.

Chart III shows that the proband has two normal siblings and that there were two abortions between these children, one in 1945 and the other in 1947. The parents (II-1 and II-2) were both born in 1922. The mother is separated from her husband and no contributory information from the paternal side of the family was available. Besides the presence of diabetes mellitus in this pedigree, the number of abortions is also of interest. Our informant (II-2) states that her sister (II-10) and her husband (II-11) sought medical advice because they wanted to have children but thus far there have been two spontaneous abortions (III-12 and III-13) for no apparent reason. Roentgenograms showed the mother's spine and pelvis to be normal.

CASE 4 (15107-M). Chart IV, II-14: This Mexican boy was born April 4, 1954. The mother had normal labor and spontaneous delivery after a full-term gestation. She did not feel well during the pregnancy and was told that she had high blood pressure. The birth weight was five pounds, two ounces.

Deformity of the legs and feet and constant dribbling of urine and faeces were noted by

the parents. The child was admitted to John Sealy Hospital on April 4, 1956. On admission, physical examination revealed the following anomalies: atrophy of the lower extremities, especially marked below the knees; marked limitation of motion at the knees; bilateral resistant talipes equinovarus; flattening of the buttocks with double symmetrical dimpling (Fig. 4-A); a horizontal rectum; and absence of anal sphincter tone. There was dislocation of the left femoral head.

Roentgenographic examination of the spine and pelvis (Fig. 4-B) revealed absence of the fifth lumbar vertebra with approximation of the ilia in the mid-line, and complete absence of the sacrum and coccyx. There was dislocation of the left femoral head into the iliac fossa. Treatment consisted in manipulative and plaster correction of the feet with moderate success. No attempt was made to reduce the hips.

FIG. 4-A

FIG. 4-B

Fig. 4-A: Case 4. Photograph showing atrophy of the lower extremities, especially marked below the knees; bilateral talipes equinovarus; and flattening of the buttocks with double symmetrical dimpling.

Fig. 4-B: Roentgenogram of the spine and pelvis showing complete absence of the spine below the fourth lumbar vertebra with approximation of the iliac in the mid-line and dislocation of the left femoral head into the iliac fossa.

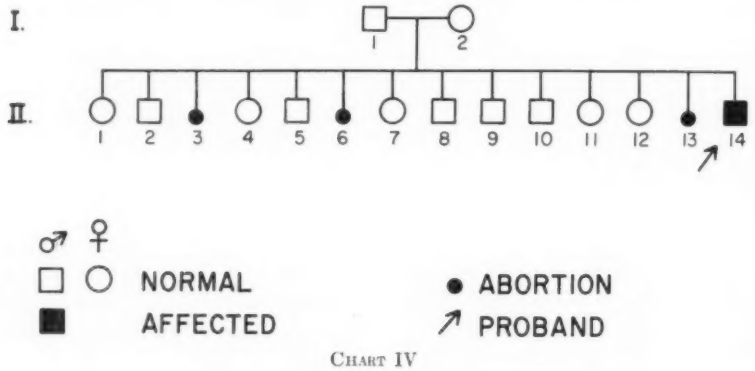


CHART IV
Case 4.

Chart IV shows that the proband has ten normal siblings and that there have been three spontaneous abortions in this pedigree; a female foetus (II-3) at four months in 1935, another female foetus (II-6) at four months in 1940, and a male foetus (II-13) at two months in 1951. The first child (II-1) died at the age of seven months from diarrhoea. The other siblings are well and apparently normal.

The proband's mother (I-2) comes from a family of nine children (three female and six male), all apparently normal and healthy. She emigrated from

FIG. 5

Case 5. Pyelogram showing bilateral hydronephrosis, most marked on the left, and also demonstrating lumbarization of the first sacral vertebra or a sixth lumbar vertebra, and absence of the distal two sacral vertebrae and the coccyx.

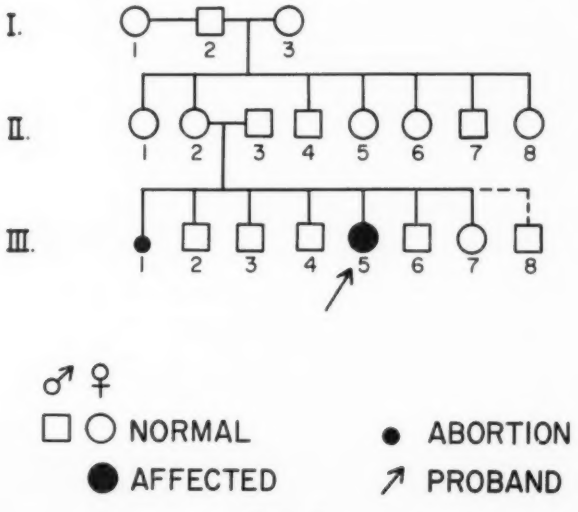


CHART V

Case 5.

Mexico and has not kept in touch with her family. The proband's father (I-1) has two siblings—a sister with two daughters, one of the daughters having a son, and a brother who is without progeny. Myopia is present on the paternal side of the family. Roentgenograms showed that the spines and pelves of the proband's mother (I-2) and sister (II-7) were normal.

FIG. 6-A

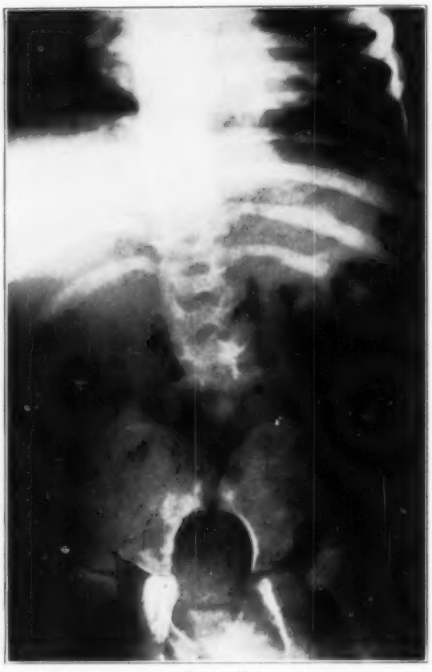


FIG. 6-B

Fig. 6-A: Case 6. Photograph showing bilateral atrophy of the muscles below the knees and bilateral talipes equinovarus with flattening and prominent dimpling of the buttocks.

Fig. 6-B: Roentgenogram of the spine and pelvis showing complete absence of the spine below the third lumbar vertebra with approximation of the ilia in the mid-line and bilateral dislocation of the femoral heads into the iliac fossae.

CASE 5 (47122-M). Chart V, III-5. This white girl was born January 5, 1950. The mother had a nine-month pregnancy, the last three months of which were accompanied by excessive vomiting and oedema. Labor and delivery were normal.

The patient was first seen at John Sealy Hospital on July 17, 1957, at which time she was admitted because of excessive and frequent urination, a condition present since birth. Examination revealed a rather thin, pale child, somewhat smaller than the average seven-year-old. There were no gross physical abnormalities other than that the coccyx could not be palpated. There was no sensory loss and no motor deficit.

Roentgenographic examination of the pelvis (Fig. 5) showed lumbarization of the first sacral vertebra or a sixth lumbar vertebra and absence of the distal two sacral vertebrae and the coccyx. Pyelography revealed bilateral hydronephrosis, more marked on the left. A diagnosis was made of paralysis of the external urethral sphincter, neurogenic urinary bladder and ureteral stricture, the latter being confirmed surgically. The patient was ultimately treated with ureterostomy.

The mother of the proband (Chart V, II-2) is of Indian ancestry on her mother's side, was married at thirteen years of age, and is now a widow. Her husband died in July 1954 at the age of thirty-five of heart failure. High blood pressure and enlarged heart are prevalent in her husband's family. In addition to the proband, there are six normal siblings in this pedigree. The youngest boy (III-8)

was born out of wedlock on March 11, 1956. III-6 died at the age of two and one-half years of leukaemia and malignant brain tumor. III-1, a girl, was stillborn.

The proband had an electro-encephalogram made on July 24, 1957, which showed a normal tracing. Psychological evaluation in August 1957 using the Revised Stanford-Binet Scale (Form L) showed that the patient is somewhat men-

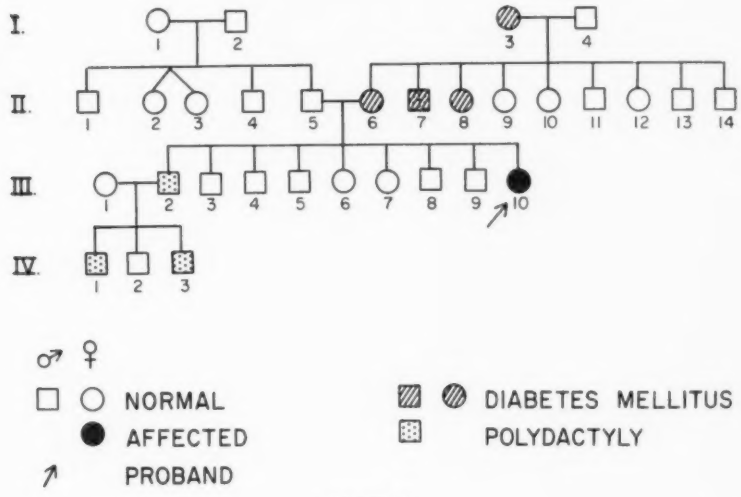


CHART VI
Case 6.

tally retarded, achieving a mental age of five years, two months at a chronological age of seven years, seven months.

CASE 6 (14829-J). Chart VI, III-10: This Negro girl was born August 26, 1953. The mother had a full-term pregnancy and normal labor and delivery. The infant was admitted to John Sealy Hospital on October 26, 1953, for repair of a cleft lip. This defect and other anomalies were noted at birth.

Physical examination on admission revealed a generally well developed child with the following anomalies: severe cleft lip extending into the right naris; umbilical hernia; bilateral dislocation of both femoral heads; marked limitation of motion in both knees with atrophy of the muscles below the knees, bilaterally; bilateral talipes equinovarus; flattening and prominent dimpling of the buttocks, bilaterally; and an almost horizontal rectum (Fig. 6-A).

Roentgenograms of the spine and pelvis (Fig. 6-B) revealed complete absence of the spine below the fifth lumbar vertebra. There was an approximation of the ilia in the midline and bilateral dislocation of the femoral heads into the iliac fossae. It was evident from subsequent observations that there was no voluntary control of bowel and bladder functions.

Treatment consisted in surgical correction of the cleft lip, gradual manipulative correction of the feet with very slow progress, and attempted manipulative correction of the hips.

Chart VI shows that diabetes mellitus and polydactylia are both present on the maternal side of the family in this kindred. The polydactylia shows variability of expression. II-7 has diabetes and extra digits on the hands and feet, and he has a daughter (not shown on chart) with what our informants (II-5 and II-6) called "ape toes", that is, small toes overlapping other toes. The eldest brother of the proband (III-2) has extra digits on both hands and has two sons (IV-1 and IV-3) who show the same anomaly. This is a large pedigree and all members not directly concerned were excluded. Roentgenograms showed the spines and pelves of the proband's parents (II-5 and II-6) to be normal.

CASE 7 (5121-K). Chart VII, III-13: This white boy was born April 2, 1954, following an uncomplicated term pregnancy. There were two days of false labor with rupture of the mem-

FIG. 7-A

FIG. 7-B

Fig. 7-A: Case 7. Photograph made when the patient was four years old, showing poor development of the lower extremities below the knees with some residual foot deformity bilaterally.

Fig. 7-B: Roentgenogram of the spine and pelvis showing fusion of the left eighth and ninth ribs at their vertebral ends; a bifid eleventh thoracic vertebra; an extra right hemivertebra with a rib between the eleventh and twelfth thoracic vertebrae; gross deformity of all lumbar vertebrae with the second and fourth lumbar vertebrae being left hemivertebrae; absence of the fourth and fifth sacral vertebrae; and absence of the coccyx.

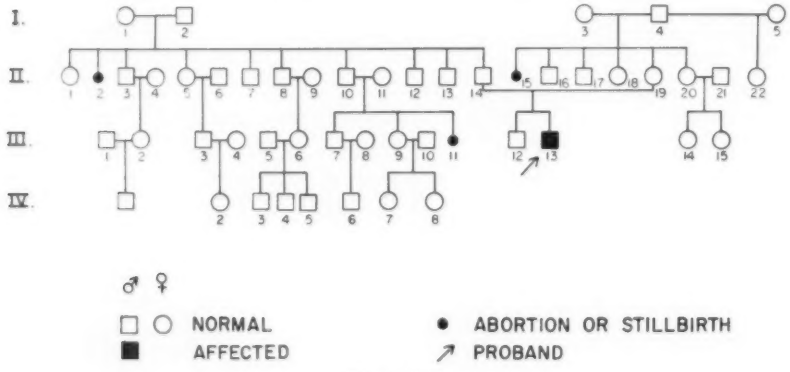


CHART VII
Case 7.

branes one week prior to delivery. Labor began again twenty-four hours before spontaneous delivery of the six-pound infant. Examination of the infant revealed an imperforate anus and deformities of the legs and feet. The child was referred to John Sealy Hospital on April 3, 1954. At this time, it was apparent that the lower extremities were poorly developed below the knees with talipes equinovarus on the left and talipes calcaneovalgus on the right (Fig.

FIG. 8-A

FIG. 8-B

Case 8. Roentgenograms of the spine and pelvis showing high thoracic scoliosis associated with minor vertebral anomalies at this level and absence of the distal three sacral vertebrae and the coccyx.

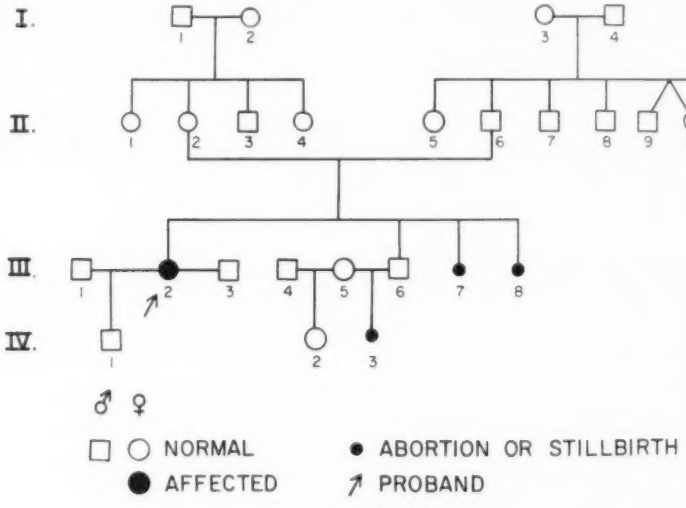


CHART VIII
Case 8.

7-A). Sensation in the lower extremities was intact. Imperforate anus and a prostatic urethral stricture were noted.

Roentgenograms of the spine and pelvis showed multiple vertebral defects extending from the lower thoracic area distalward. The imperforate anus was corrected and during this procedure, a recto-urethral fistula was found and repaired. Suprapubic cystostomy was performed, and plaster correction of the feet was begun. The feet were eventually sufficiently corrected for weight-bearing and the child became ambulatory with a walker.

Recent roentgenograms (Fig. 7-B) show more clearly the following: fusion of the left eighth and ninth ribs at their vetebral ends; a bifid eleventh thoracic vertebra; an extra right hemivertebra with a rib between the eleventh and twelfth thoracic vertebrae; gross deformity

of all lumbar vertebrae with the second and fourth being left hemivertebrae; absence of the distal two sacral vertebrae; and absence of the coccyx. Subsequent urological study revealed absence of the right kidney and hydronephrosis of the left kidney. Ureterostomy with ileal conduit was performed and drainage of the left kidney has improved.

The parents of the proband (Chart VII, II-14 and II-19), in an interview, claimed that theirs was a planned family; however, no chemical contraceptives had been used. History on the maternal side of the family revealed that there was a male stillbirth (II-15). II-16 died in 1939 at the age of twenty-five years of malignant nevus. II-18 died when only a few weeks old from unknown causes. II-22 was delivered by breech presentation and has a curvature of the spine. III-14 has rheumatic fever and III-15 suffers from numerous allergies.

The paternal history disclosed that IV-6 was born with cyanotic cardiac disease. III-11 was a stillbirth. II-1 died at the age of seven months of intermittent fever. II-2 was a female stillbirth and II-7 died at the age of four years of croup.

Roentgenograms revealed the spines and pelves of the proband's parents (II-14 and II-19) and older brother (III-12) to be normal.

Case 8 (11807-E). Chart VIII, III-2: This white woman, born April 21, 1909, has been treated at John Sealy Hospital for recurrent urinary complaints since 1953. Her first admission to the hospital in 1948 was for correction of inguinal hernia. Her second hospital admission in July 1954 was for evaluation of chronic cystitis for which she underwent cystoscopic and pyelographic examination. On her third admission in February 1958 a diagnosis of bilateral pyelonephritis associated with vesico-ureteral reflux was made. The urinary bladder was described as showing extensive trabeculation, probably neurogenic in origin.

Roentgenograms (Figs. 8-A and 8-B) revealed the incidental findings of: high thoracic scoliosis associated with minor vertebral anomalies at this level, and absence of the distal three sacral vertebrae and the coccyx.

Interviews with the proband (Chart VIII) disclosed the following additional information. The proband's mother had a normal pregnancy, labor, and delivery; however, the proband was weak at birth and held her head to one side. She was delicate in her youth, had pleurisy at the age of one year, and suffered from constipation and weakness of the bladder. At the age of twenty-three she had a severe attack of pyelitis. In her third month of pregnancy she was told that her child would have to be delivered by Cesarean section because of her physique and fibroid tumors in the uterus. According to the proband, no roentgenographic studies were made at that time. She tired easily during her pregnancy. She had an episode of acidosis six weeks prior to the birth of her son. This persisted for twelve days post partum. At this time the fibroid tumors were removed and the fallopian tubes ligated.

In 1951, she had a hysterectomy, appendectomy, and "straightening" of the colon performed.

Additional information in regard to her family history reveals that on the paternal side the proband's grandmother (I-3) had a double hernia; II-8 died at age sixty years and one of twins (II-10) died at birth; the other twin died at the age of two or three months. II-11 died of Parkinsonism. On the maternal side of the family II-4 died at the age of four of diphtheria. The proband has one brother (III-6) whose wife has a normal child by a previous marriage. It is apparently not possible for the present union to produce children. There has been one spontaneous abortion (IV-3). Our informant, the proband, stated that her mother had always been rather evasive about her two abortions (III-7 and III-8). One other point of interest is that individuals on the maternal side of the family have so-called "short necks."

RESULTS AND DISCUSSION

Table I summarizes results in fifty patients, twenty-seven male and twenty-three female, of complete (thirty-two cases) and partial (eighteen cases) absence or malformation of the sacrum with associated anomalies.

Cases 1 through 8, from John Sealy Hospital (Table I and Charts I through VIII), have been reported in sufficient detail in order to be of value for future workers who might wish to use them for genetic analysis.

Roentgenograms and brief descriptions of Cases 12, 13, 14, 15, and 16 in Table I were published by Shands and Bundens. No case histories were reported by these authors. Case 35 (Table I) may have been reported by Zeligs in 1940.

To our knowledge, the remaining cases have not been reported in the literature.

Table I reveals that the most severe vertebral malformation in this study occurs in Case 37. Here the spine is absent below the twelfth thoracic vertebra. Only two patients more severely affected were found in the literature. Friedel reported a female patient with absence of the spine below the tenth thoracic vertebra and Sinclair and associates reported a boy with absence of the spine below the eleventh thoracic vertebra. In Cases 34 and 48 the lowest vertebra present is the first lumbar. Of our own eight cases, the patient in Case 6 is the most severely involved. The spine is absent below the third lumbar vertebra, and in Case 4 the spine is absent below the fourth lumbar vertebra. From these extremes there is a gradation to Cases 1, 13, and 29 where only malformations are shown.

Table I reveals that this study includes four Mexicans, three Negroes, forty-one white patients and two whose race is unknown.

The incidence of defects associated with complete and partial absence of the sacrum and coccyx are summarized in Table I. There were fourteen cases of spina bifida. Meningocele was present in five patients. Defects in the lower extremities included twenty-seven cases of club-foot. Twenty-one of these patients are in the group with complete absence of the sacrum and coccyx. Paralysis was present in four patients, atrophy in five, and contractures in ten. In all of these the percentage of defect is much higher in the group with complete absence. This is also true in patients with dislocated hips. Arthrogryposis was demonstated in six patients, bladder or bowel dysfunction, or both, in ten and anal defects in five. Cleft lip or palate, or both, was present in three patients. Herniae were present in four patients; three of the four were female.

Miscellaneous concomitant anomalies (Table I) were: strabismus; ureteral stricture; undescended testicle; urethral stricture; absence of right kidney; recto-urethral fistula; rectovaginal fistula; absence of middle phalanges of all toes of the left foot except the first; dysplasia of the right hip; coxa vara of the right hip; bilateral coxa vara; synostosis; congenital cardiac disease; microcephaly; anophthalmos, left eye; ankylosis of the mandible and maxilla; reduplication of colon, penis, and bladder; bilateral absence of fibulae; fusion of the left ankle and foot in dorsiflexion; defect of cord; rudimentary lower extremities; shallow acetabulae; anaesthesia below the knees; deformed pelvis; and various rib anomalies.

Table I summarizes the types of delivery and the possible related etiological factors in addition to heredity.

Anomalies in collaterals and ascendants were present in 22 per cent of all patients. These include diabetes mellitus (Cases 3 and 6), polydactylism (Case 6), "intoe deformity" of one foot (Case 17), internal strabismus (Case 26), achondroplasia (Case 28), congenital anomalies of the thumb (Case 40), club-foot (Cases 35 and 42), congenitally dislocated hips (Case 44), meningocele (Case 35), deaf-mutism (Case 38), and Legg-Perthes disease (Case 29).

Abortions occurred in seven women of the fifty families. Three of the seven were among our own eight cases and it is conceivable that more detailed family histories of all patients would lead to detection of additional spontaneous abortions in individuals from families with cases of sacral agenesis.

Breech presentation was the method of delivery of approximately 18 per cent of the patients. Cesarean section was performed for one patient. There were two premature and postmature births. Actually, the number of premature births in this report would be greatly increased if birth weights were used as the criteria for prematurity.

According to Foix and Hillemand's classification, sacrococcygeal agenesis can be divided into four types depending on the degree of involvement. Most of the cases in this study fit this classification. The clinical features such as skeletal, visceral, and neurological abnormalities manifested in the patients in this report closely parallel those published previously and discussed by the authors.

The phylogenetic loss of a tail in man is of interest from a purely evolutionary standpoint. In the animal kingdom loss of the caudal portion of the vertebral column is not uncommon. Rumplessness in fowls was known to Highmore in 1651 and still occurs spontaneously in fowl populations. Danforth produced artificial and hereditary suppression of sacral vertebrae in the fowl. Landauer produced rumplessness in chicken embryos by the injection of insulin and other chemicals. The injection of insulin produced complete rumplessness or variations between this condition and a normal tail. Duraiswami also induced skeletal abnormalities in developing chickens by the injection of insulin. Baldwin artificially produced spina bifida in frogs by the action of ultra-violet rays upon the eggs. In 1896, Hertwig reported the production of spina bifida in frog embryos by various chemical and temperature changes. Warkany and associates produced malformation in rats by maternal nutritional deficiencies. One of the more striking reports is by Dunn and associates on a mutation in the mouse, first found by Danforth to affect the spinal column and urogenital system. In the heterozygous (gene present once) condition in these animals the sacral region is frequently shortened, with occasional scoliosis or lordosis; either one or both kidneys are missing or abnormally small. Mice homozygous (gene present twice) for this condition die within twenty-four hours after birth. They always have imperforate anus and partial or complete absence of kidneys and other parts of the urinary and genital system. The spine ends in the lumbar region.

Zilva and associates reported pigs without hind limbs. These were produced by sows fed on diets deficient in Vitamin A. Freedman stated these are reminiscent of Brack's case where the lower limbs in a human stillborn appeared to be completely absent, but upon roentgenographic examination a left femur was found with indications of a vestigial left tibia and right femur.

The few instances cited previously furnish evidence of the diversity of ways by which anomalies may be produced. Thus, it is conceivable that certain illnesses, the presence of toxic substances in the maternal circulation during pregnancy, or pyrexia might have a teratological effect on the developing embryo. Whether some genotypes are affected more frequently than others by certain conditions operating during early fetal development is one of the many questions asked in this long-term investigation. Some cases of sacral agenesis are probably due entirely to heredity. Whether this is due to recurrent mutations or the chance combination of recessive genes and their modifiers or both is still a matter of speculation. Only one instance where absence of the sacrum was inherited from father to son is recorded in the literature [49]. One approach in elucidating this problem was to examine roentgenographically the spines and pelves of the probands' families. So far, roentgenograms made of one or both parents in Cases 2, 3, 4, 6, and 7 and the proband's sister in Case 4 and brother in Case 7, reveal normal findings.

SUMMARY

1. Fifty cases of complete or partial agenesis or malformation of the sacrum with associated anomalies have been reported. These include members of the Mexican, Negro, and white population.

2. In thirty-two cases reported there is complete absence of the sacrum and coccyx, and in eighteen there is partial absence or malformation of the sacrum and coccyx.

3. Vertebral defects in these patients range from complete absence of the spine below the twelfth thoracic vertebra to minor malformations.

4. Associated anomalies include spina bifida; meningocele; club-foot; paralysis; atrophy; contractures; dislocated hips; arthrogryposis; bladder or bowel dysfunction or both; anal defects; cleft lip or cleft palate, or both; and herniae. Other concomitant anomalies present are reported.

5. Possible related, contributing etiological factors such as complications of

pregnancy, diabetes mellitus in the probands' mothers, spontaneous abortions, and types of gestation and deliveries are presented.

6. Anomalies in collaterals and ascendants are reviewed.

7. Spontaneous and artificial production of spine anomalies in animals and their genetic implications have been discussed.

ACKNOWLEDGMENT: The authors wish to express their appreciation and gratitude to the surgeons and hospitals for their response regarding cases of sacral and coccygeal agenesis and for permission to use them in this study.

REFERENCES

1. ADDISON, JOHN: Sacro-coccygeal Agenesis. Proc. Roy. Soc. Med., **48:** 163-164, 1955.
2. DE ARAÚJO, ACHILLES: Distrofia cruro-vesico-glutea por agenesia total do sacro-coccyx. Arq. Brasileiros Cir. e Ortop., **4:** 43-59, 1936.
3. BALDWIN, W. M.: The Action of Ultra-violet Rays upon the Frog's Egg. I. The Artificial Production of Spina Bifida. Anat. Rec., **9:** 365-381, 1915.
4. BARROS LIMA: A proposito de un caso de malformaçao do sacro. Arq. Brasileiros Cir. e Ortop., **3:** 195-200, 1935.
5. BAUER, O.: Totale Aplasie der Lendenwirbelsäule bei einem Neugeborenen. Geburtsh. u. Frauenh., **12:** 250-256, 1952.
6. BERMAN, WILLIAM: Congenital Absence of the Sacrum and Coccyx Complicating Pregnancy. Am. J. Obstet. and Gynec., **50:** 447-450, 1945.
7. BLOOM, C. J.; STONE, R. E.; and HENRIQUES, ADOLPH: Three Unusual Cases of Congenital Origin. Arch. Pediat., **34:** 512-515, 1917.
8. BRACK, E.: Über das Kreuzbein. Virchow's Arch. f. Path. Anat., **272:** 295-304, 1929.
9. BRADBURN, W. P.: The Report of an Interesting Case of Infected Bladder and Kidneys Producing Primary Symptoms and Unrecognized as such on account of Malformation of Sacrum. New Orleans Med. and Surg. J., **74:** 633-636, 1922.
10. BRAILSFORD, J. F.: Deformities of the Lumbosacral Region of the Spine. British J. Surg., **16:** 562-627, 1929.
11. DANFORTH, C. H.: Artificial and Hereditary Suppression of Sacral Vertebrae in the Fowl. Proc. Soc. Exper. Biol., **30:** 143-145, 1932.
12. DEL DUCA, VINCENT; DAVIS, E. V.; and BARROWAY, J. N.: Congenital Absence of the Sacrum and Coccyx. Report of Two Cases. J. Bone and Joint Surg., **33-A:** 248-252, Jan. 1951.
13. DESCHAMPS: Un cas de spina bifida avec absence du sacrum. Ann. d'Orthop. et Chir. Prat., **7:** 367, 1894.
14. DESFOSSES, PAUL, and MOUCHET, ALBERT: Absence du sacrum et des deux dernières vertèbres lombaires. Rev. d'Orthop., **11:** 61-70, 1924.
15. DIAZ LIRA, E: Agenesia sacrococcigea. Rev. Ortop. y Traumatol., **7:** 231-237, 1938.
16. DUNN, L. C.; GLUECKSOHN-SCHOENHEIMER, S.; and BRYSON, VERNON: A New Mutation in the Mouse Affecting Spinal Column and Urinogenital System. J. Hered., **31:** 343-348, 1940.
17. DURAISWAMI, P. K.: Insulin-Induced Skeletal Abnormalities in Developing Chickens. British Med. J., **2:** 384-390, 1950.
18. ELMSLIE, R. C.: Case of Congenital Absence of Sacrum, with Associated Dislocation of One Hip and Talipes Calcaneo-valgus. Proc. Roy. Soc. Med., **15:** 8, 1921.
19. FELLER, A., and STERNBERG, H.: Zur Kenntnis der Fehlbildungen der Wirbelsäule. III. Mitt. Über den vollständigen Mangel der unteren Wirbelsäulenabschnitte und seine Bedeutung für die formale Genese der Defektbildungen des hinteren Körperendes. Virchow's Arch. Path. Anat., **280:** 649-692, 1931.
20. FÉRÉ, C.: Une anomalie du coccyx chez un épileptique. N. Iconog. de la Salpêtrière, **5:** 89-91, 1892.
21. FITCH, R. R.: Congenital Absence of Vertebrae Below the First Sacral, and Malformation of the Lower Cervical and Upper Dorsal Vertebrae. Am. J. Orthop. Surg., **7:** 540-543, May 1910.
22. FOIX, C., and HILLEMAND, P.: Dystrophie cruro-vésico-fessière par agénésie sacro-coccygienne. Rev. Neurol., **40:** 450-468, 1924.
23. FREEDMAN, BERNARD: Congenital Absence of the Sacrum and Coccyx. Report of a Case and Review of the Literature. British J. Surg., **37:** 299-303, 1950.
24. FRIEDEL, G.: Defekt der Wirbelsäule vom 10. Brustwirbel an abwärts bei einem Neugeborenen. Arch. f. Klin. Chir., **93:** 944-958, 1910.
25. FROELICH, M.: Absence Congénitale d'une moitié du sacrum. Rev. Méd. de l'Est, Nancy, **37:** 308, 1905.
26. GIANNINI, M. J.; BORELLI, F. J.; and GREENBERG, W. B.: Agenesis of the Vertebral Bodies—A Cause of Dwarfism. Am. J. Roentgenol. **59:** 705-711, 1948.
27. GIRARD, P. M.: Congenital Absence of the Sacrum. J. Bone and Joint Surg., **17:** 1062-1064, Oct. 1935.
28. GUILLEMINET, M.: Agénésie subtotale du sacrum et du coccyx. Lyon Chir., **35:** 369, 1938.
29. HAMSA, W. R.: Congenital Absence of the Sacrum. Arch. Surg., **30:** 657-666, 1935.
30. HERTWIG, O.: Experimentelle Erzeugung Thierischer Missbildungen. Forstschr. f. Gegenbaur, **2:** 87, 1896.
31. HIGGS, S. L.: Specimen of Congenital Absence of the Sacrum. Proc. Roy. Soc. Med., **17:** 39, 1924.
32. HIGHMORE, NATHANIEL: The History of Generation; examining the several opinions of divers authors, especially that of Sir K. Digby, in his Discourse of bodies . . . To which

is joyned. A discourse of the Cure of Wounds by sympathy . . . especially by that powder known chiefly by the name of Sir Gilbert Talbot's powder. London, J. Martin, 1651.
33. Hilgenreiner, H: Ein Fall von Anchypodie Beitrag zum vollständigen Kreuzbeindefekt. Zeitschr. f. Orthop., **66:** 224-232, 1937.
34. Hohl, A. F.: Zur Pathologie des Beckens. I. Das schräg-ovale Becken, p. 61. Leipzig, Wilhelm Engelmann, 1852.
35. Jarcho, Saul, and Levin, P. M.: Hereditary Malformation of the Vertebral Bodies. Bull. Johns Hopkins Hosp., **62:** 216-226, 1938.
36. Jaroš, M.: Vrozené aplasie kosti křižové; dyspygia. Acta Chir. Orthop. et Traumatol. Čechoslovaca, **23:** 293-296, 1956.
37. Jorge, J. M., and Jorge, H.: Agenesias sacrococcigeas (totale y subtotales). Rev. Asoc. Med. Argentina, **62:** 389-398, 1948.
38. Katz, J. F.: Congenital Absence of the Sacrum and Coccyx. J. Bone and Joint Surg., **35-A:** 398-402, Apr. 1953.
39. Kienböck, R., and Zimmer, A.: Angeborener partieller Kreuz-und Steissbeindefekt. Röntgenpraxis, **7:** 111-113, 1935.
40. Kratochvíl, L., and Zdenković, A.: Kasuistischer Beitrag zur Myelodysplasie mit sakrokokzygealer Agenesie (Case report of myelodysplasia with sacrococcygeal agenesis). Zentral. f. Chir., **81:** 2346-2354, 1956.
41. Lamoot, J., and Graux: Agénésie sacro-coccygienne. Echo Med. du Nordisk, **5:** 88-90, 1936.
42. Landauer, Walter: Rumplessness of Chicken Embryos Produced by the Injection of Insulin and Other Chemicals. J. Exper. Zool., **98:** 65-77, 1945.
43. Léri, A., and Linossier, A.: Un cas de dystrophie cruro-vésico-fessière par agénésie du sacrum. Bull. et Mém. Soc. Méd. Hôp. Paris, **49:** 12-17, 1925.
44. Léri, A.; Pettidi; and Cottenot: Anomalie du sacrum. Bull. et Mém. Soc. Méd. Hôp. Paris, **48:** 1173-1175, 1924.
45. Lichtor, Alexander: Sacral Agenesis. Report of a Case. Arch. Surg., **54:** 430-433, 1947.
46. Müller, J. H.: Ein Fall von Aplasie des Sacrum. Röntgenpraxis, **8:** 105-106, 1936.
47. Newell, J. L.: A Case of Multiple Congenital Anomalies of the Müllerian and Genitourinary Systems with Absence of the Coccyx. New England J. Med., **210:** 1217-1218, 1934.
48. Pirkey, E. L., and Purcell, J. H.: Agenesis of Lumbosacral Vertebrae. A Report of Two Cases in Living Infants. Radiology, **69:** 726-729, 1957.
49. Pouzet, F.: Les anomalies de développement du sacrum. Lyon Chir., **35:** 371-373, 1938.
50. Price, P. B.: Plastic Operations for Incontinence of Urine and of Feces. Arch. Surg., **26:** 1043-1053, 1933.
51. Rendu, André, and Verrier, H.: Absence Partielle du sacrum, pieds bots Congenitaux varus équin et talus valgus, malformation de l'anus, troubles paralytiques, luxation bilatérale des hanches et microcéphalie. Rev. d'Orthop., **4:** 311-314, 1913.
52. Salvat Espasa, M.: Un caso de agenesia del sacro. Distrofia vésico-gluteocrural. Rev. Med. de Barcelona, **9:** 547-551, 1928.
53. Shands, A. R., Jr., and Bundens, W. D.: Congenital Deformities of the Spine. An Analysis of the Roentgenograms of 700 Children. Bull. Hosp. Joint Dis., **17:** 110-133, 1956.
54. Sinclair, J. G.; Duren, Norman; and Rude, J. C.: Congenital Lumbosacral Defect. Arch. Surg., **43:** 473-478, 1941.
55. Soothill, J. F.: Congenital Absence of the Sacrum and Coccyx. Guy's Hosp. Rep., **103:** 87-91, 1954.
56. Stephens, F. D.: Congenital Imperforated Rectum, Recto-urethral and Rectovaginal Fistulae. Australian and New Zealand J. Surg., **22:** 161-172, 1953.
57. Stewart, S. F.: Absence of Sacrum. With Report of a Case, and a Review of the Literature. Arch. Surg., **9:** 647-652, 1924.
58. Storm-Mathisen, A.: Myelodysplasia with Absence of Sacrum (One Case). Acta Psychiat. et Neurol. Scandinavica, **29:** 145-149, 1954.
59. Thompson, I. M., and Hooks, C. A.: The Urologic Significance of Imperforate Anus. Am. Surg., **22:** 1112-1116, 1956.
60. Torgersen, Johan: Anomalies of the Spine in Anomalies of Viscera and Constitution. Acta Radiol., **29:** 311-320, 1948.
61. Warkany, Josef; Nelson, R. C.; and Schraffenberger, Elizabeth: Congenital Malformations Induced in Rats by Maternal Nutritional Deficiency. III. The Malformations of the Extremities. J. Bone and Joint Surg., **25:** 261-270, Apr. 1943.
62. Wertheim, C. C.: Vollständiger Mangel des Kreuz-und Steissbeins bei einem Neugeborenen. Monatschr. f. Geburtsk. u. Frauenkr., **9:** 127, 1857.
63. White, Clifford: A Foetus with Congenital Absence of the Sacrum. Proc. Roy. Soc. Med., **4:** 279-280, 1911.
64. Willemin, F.: Spondyloptose par agénésie de la base sacrée. J. Radiol. et Électrol., **21:** 57-61, 1937.
65. Williams, D. I., and Nixon, H. H.: Agenesis of the Sacrum. Surg., Gynec., and Obstet., **105:** 84-88, 1957.
66. Zeligs, I. M.: Congenital Absence of the Sacrum. Arch Surg., **41:** 1220-1228, 1940.
67. Zilva, S. S.; Golding, John; Drummond, J. C.; and Coward, K. H.: The Relation of the Fat-Soluble Factor to Rickets and Growth in Pigs. Biochem. J., **15:** 427-437, 1921.

Reconstruction of a Digit Following Loss of All Fingers with Preservation of the Thumb*

BY G. N. LASSAR, M.D., ST. LOUIS, MISSOURI

From the Division of Surgery, The Jewish Hospital of St. Louis and The Department of Surgery of St. Louis University, St. Louis

The initial care of a wound of the hand is the most important step in its treatment [5]. Although the first task is that of débridement and wound closure, it is beneficial to plan at that time for reconstruction. In fact, reconstruction actually starts with initial care because its possibilities and limitations are frequently determined by the status created by the first definitive treatment. The following case is reported because it illustrates certain advantages derived from the application of this and other principles in the surgical treatment of the severely injured hand.

FIG. 1-A

FIG. 1-B

Fig. 1-A: Photograph of the anterior view of the hand made at the time of initial surgery. The palmar flap has been advanced to cover the ends of the metacarpals and is being held in position with towel clips.

Fig. 1-B: Dorsal view showing distal margin of the palmar-skin flap partially sutured to dorsal-skin margin.

On March 2, 1956, the patient's right hand was caught in a punch press and mangled to the extent that traumatic amputation resulted extending obliquely from the head of the metacarpal of the index finger, across the palm, to the base of the fifth metacarpal; however, the thumb was spared. Parallel to the plane of amputation ran a deep laceration at the base of the palm, exposing the muscles of the thenar eminence and the median nerve. As indicated in Figures 1-A and 2, this laceration delineated a flap of palmar integument which proved to be adequately vascularized. Definitive wound treatment was carried out with the patient under general anaesthesia two hours after the accident. The skin was washed with septisol solution and the wound irrigated with saline. Débridement was performed with scalpel and scissors and the jagged fracture lines of the metacarpals were rounded with a rongeur.

How to close the plane of amputation and the laceration at the base of the palm had to be decided. The following possibilities were considered:

Application of a split-thickness graft was out of the question since the ends

* Read at the Annual Meeting of the American Society for Surgery of the Hand, Chicago, Illinois, January 24, 1959.

of the metacarpals were exposed; even if these could be covered with muscle and subcutaneous tissue, it was felt that such a cover, over an area which would have to withstand trauma, was at best only a temporary measure.

Primary closure would require resection of at least two centimeters of the remaining metacarpals; this hardly seemed prudent in view of the loss already sustained.

An abdominal flap would serve adequately but it had the disadvantages common to application of a distant flap compared with that of a local flap. Furthermore, abdominal skin which remains anaesthetic and unable to withstand injury is not desirable in any area which is subject to frequent trauma [1].

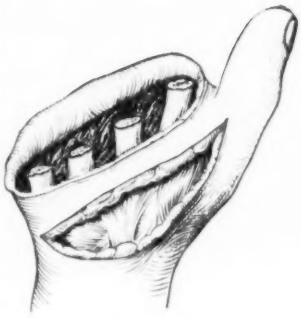


FIG. 2

Diagrammatic drawing of the original injury showing the level of amputation and secondary laceration across the palm of the hand.

Flap advancement seemed to offer the best solution because: (1) a flap had already been created by the injury; (2) this would permit the stump to be covered by palmar skin for which there is no adequate substitute; and (3) further reconstructive work would be somewhat simplified by the presence of a palmar pad having good sensation.

Accordingly, the palmar flap was sutured to the dorsal-skin margin thereby covering the stump (Fig. 1-B). The median nerve was inspected and appeared

FIG. 3-A

FIG. 3-B

Fig. 3-A: Anterior view of the hand made on May 28, 1956, two months after injury. Cleft between the thumb and the metacarpal of the index finger has been completely obliterated.
Fig. 3-B: Roentgenogram of the hand made at the same time to show remnants of metacarpals.

intact although the motor component to the thenar muscles could not be identified without further dissection which was not felt to be expedient at the time. It was possible to cover the nerve with palmar fascia and the defect, resulting from the flap advancement, was covered by a split-thickness graft taken from the left thigh (Fig. 4-A). The graft was held in position with a sea sponge stent and a pressure dressing was then applied. Sequestrectomy of the distal end of the metacarpal of the index finger had to be performed on May 10, 1956; by May 28, 1956, the stump was well healed. Figure 3 shows the condition of the hand at this time. There was approximately 50 per cent limitation of thumb motion and complete obliteration of the cleft between the thumb and index finger. The patient was put on an intensive physical therapy regimen which included application of a dynamic splint designed to increase the motion of the thumb. Some improvement followed in the ensuing months but there was still much to be desired.

The next problem was to restore grasping function in the hand. Much of what has been learned from the abundance of material found in the literature [1,3,4] is ap-

plicable to the reconstruction of an opponent to the thumb. In this case the problem was twofold: (1) mobilization of the thumb; and (2) restoration of an opponent to the thumb. The latter may be accomplished in several ways. If the heads of the fourth and fifth metacarpals remain, against which a mobile thumb can be opposed, no further action is necessary. With a functioning thumb, most amputees are fitted with a partial prosthesis [6] in the form of a hook or rigid device against which the thumb may work. Opposition can also be achieved by deepening the thumb cleft. If necessary, the metacarpal of the index finger can be removed and utilized to lengthen a digit [2]. An opposing digit-like structure can also be constructed by means of a tubular pedicle and bone graft [1,7]. A digit can be transplanted from the uninvolved to the injured hand [8].

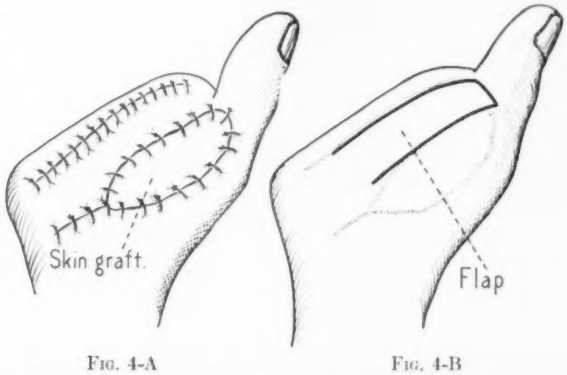


FIG. 4-A FIG. 4-B

Fig. 4-A: Drawing of the hand following initial surgical repair to show palmar flap advanced and sutured to the skin margin on the dorsum. Defect closed by split-thickness graft.

Fig. 4-B: Drawing made prior to reconstructive surgery showing the skin flap outlined by dark line.

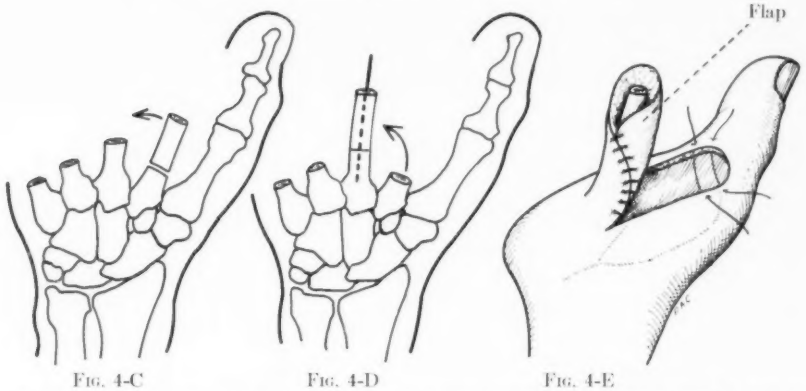


FIG. 4-C FIG. 4-D FIG. 4-E

Figs. 4-C and 4-D: Drawings made to show technique used for reconstruction of a digit by removing a portion of the metacarpal of the index finger and thrusting it into the stump of the metacarpal of the middle finger.

Fig. 4-E: Skin flap has been raised, wrapped around bone, and sutured to itself.

RECONSTRUCTIVE PROCEDURE

The thumb was mobilized by capsulotomy at the metacarpophalangeal joint on July 22, 1956. At the same time an incision was made across the palm following the lower border of the skin flap previously used to cover the ends of the metacarpals. The second and third metacarpals were exposed and the distal three-

quarters of the second metacarpal was removed. The proximal end was then shaped and inserted into the medullary cavity of the third metacarpal. Position was maintained by an intramedullary Kirschner wire. The palmar flap was remobilized and cut across at the thenar attachment. It was then swung around the protruding bone graft and sutured to itself, thereby furnishing an adequate cover of functional skin (Figs. 4-B through 4-E). The hand was immobilized in a pressure dressing and a plaster splint. Following healing, physical therapy was begun in order to strengthen and mobilize the thumb sufficiently to oppose the newly formed digit. The patient developed considerable dexterity so that he was able to use the reconstructed hand for feeding himself, writing, and performing many functions requiring grasp (Figs. 5-A, 5-B, and 5-C).

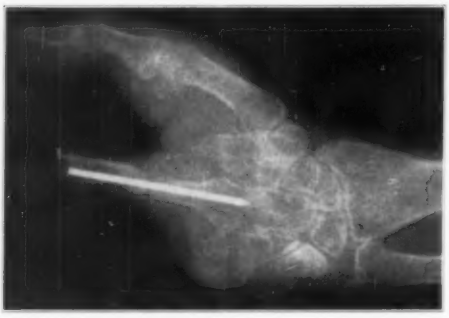


FIG. 5-A

Roentgenogram made shortly after reconstruction of the digit to show the Kirschner wire in position.

In order to evaluate this reconstructive procedure, we interviewed twelve patients with similar defects who wore work prostheses. The consensus was that the appliance served well for strenuous manual labor. However, for finer, more discriminating

FIG. 5-B

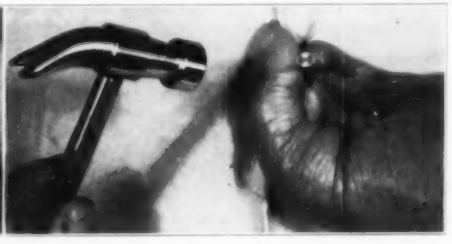


FIG. 5-C

Fig. 5-B: Photograph of the anterior surface of the healed hand showing opposition of the thumb against reconstructed digit. Pigmented area represents skin graft.

Fig. 5-C: Photograph showing patient using a newly formed digit to hold a nail.

functions of the hand it was unsuitable. Therefore, if palmar skin is available, this procedure could be advantageous, particularly in those patients whose injury involves the dominant hand or when it is desirable to retain stereognosis and tactile sensation, such as in blind patients or in those individuals whose work requires sensitive use of the hand rather than strenuous manual labor.

Most reconstructive procedures are accused of entailing too many operations over too long a time. The rehabilitation of this patient was accomplished during a period of twelve months and required only two surgical procedures, the initial surgery and the reconstructive surgery. The success of the operation obviously depended on the advancement of the palmar flap to close the wound. The transverse laceration through the base of the palm, leaving a flap available made success possible.

REFERENCES

1. BUNNELL, STERLING: Surgery of the Hand. Ed. 3. Philadelphia, J. B. Lippincott Co., 1956.
2. CANNON, B.; GRAHAM, W. C.; and BROWN, J. B.: Restoration of Grasping Function Following Loss of All Five Digits. Surgery, **25**: 420-423, 1949.

3. KELIKIAN, H., and BINTCLIFFE, E. W.: Functional Restoration of the Thumb. Pollicization of the Index. Surg., Gynec., and Obstet., **83**: 807-814, 1946.
4. LEWIN, M. L.: Partial Reconstruction of Thumb in a One-Stage Operation. J. Bone and Joint Surg., **35-A**: 573-576, July 1953.
5. MASON, M. L.: Hand Injuries. The Immediate Treatment of Acute Open Wounds. Indust. Med. and Surg., **22**: 378-392, 1953.
6. MAXIM, E. S.; WEBSTER, F. S.; and WILLANDER, D. A.: The Cornpicker Hand. J. Bone and Joint Surg., **36-A**: 21-29, Jan. 1954.
7. MÜLLER, G. M.: Construction of a Palmar Post. British J. Plast. Surg., **3**: 47-49, 1950.
8. MURRAY, A. R.: Reconstructive Surgery of Hand. Special Reference to Digital Transplantation. *In* Year Book of General Surgery 1947, pp. 653-655. Edited by Evarts A. Graham, M.D. Chicago, The Yea Book Publishers, 1947.

DISCUSSION

DR. GEORGE S. PHALEN, CLEVELAND, OHIO: I am in accord with all the principles emphasized in Dr. Lassar's paper. Dr. Lassar was fortunate to have a palmar-skin flap cut and ready to be advanced to supply skin with normal sensation over the end of the stump. In a badly contused and mangled hand, it is not often feasible or even advisable to carry out the additional dissection necessary to advance a large local skin flap. Such a procedure may contaminate a portion of the hand which was not originally involved. There is also the danger of ischaemic necrosis of a portion of the flap due to vascular trauma from the original injury.

The use of a primary abdominal pedicle flap is more often the procedure of choice. A pedicle flap never develops the sensation of palmar skin, but a very satisfactory degree of tactile sensation usually develops.

In many of the cornpicker and punch-press injuries, the thumb is fortunately spared. The presence of a normal thumb makes reconstruction of the hand much easier. As Dr. Lassar showed us, a thumb and one digit will usually provide good function.

DR. LASSAR (closing): I would like to add that following these various reconstruction procedures, particularly when an attempt is made to save sensation, the patient frequently has a weak hand which can be fitted with a prosthesis for heavy work. Sometimes in the reconstructed hand with intact sensation finer types of work can be done.

Corrosion in a Device for Fracture Fixation*

BY JONATHAN COHEN, M.D., AND GEORGE HAMMOND, M.D., BOSTON, MASSACHUSETTS

From the Department of Orthopaedics and Division of Laboratories and Research, Children's Medical Center, and Department of Orthopaedic Surgery, Lahey Clinic, Boston

All reviews of recent advances in orthopaedics emphasize the increasingly important role which metallic devices play as means of internal fixation of fractures and as internal prostheses. Successes with these devices, new or old, have been reported extensively, but failures have received less attention. Some failures are mentioned, almost in passing, as events to be expected when many cases of the disease entity or surgical procedure are reviewed [9]. The failures have generally been analyzed as clinical problems, so that few reports of metallurgical or engineering investigation of breakage or corrosion of metallic surgical devices are available [2,3,5,14]. This case of the failure of an internal device for the fixation of a fracture is presented to acquaint practitioners with the need for thorough investigation of such failures and to indicate several directions in which such investigation can be fruitful.

A woman, sixty-seven years old, was admitted to the hospital on December 14, 1954, because of severe pain in the right hip and inability to walk following a fall. On physical examination, the right lower extremity was externally rotated and shortened, and there was marked tenderness in the right hip. In addition to the fracture of the right hip, the following medical diagnoses were made: arteriosclerotic and hypertensive heart disease with slight enlargement of the heart, dilation and sclerosis of the proximal aorta, and arteriosclerosis obliterans of moderate degree. Congestive heart failure was not present. Laboratory examination of the blood and urine gave results essentially within normal limits with the exception of a hemoglobin of 10.5 grams and a hematocrit reading of 31.

Roentgenographic examination revealed a severely comminuted intertrochanteric and subtrochanteric fracture of the femur (Fig. 1). A longitudinal fracture separated a large fragment, the outer half of the upper third of the shaft of the femur, from the main distal fragment. Marked coxa vara was obvious.

On admission, the patient was placed in Russell traction for control of pain and reduction of the fracture. On December 23, after thorough medical preparation including three blood transfusions, open reduction was performed. The large segment of the upper third of the shaft was mobilized and fixed to the distal fragment by two screws. The intertrochanteric and subtrochanteric portion of the fracture was immobilized by a Smith-Petersen nail bolted to a Thornton plate held by six screws. At the conclusion of the procedure the reduction appeared satisfactory, considering the degree of comminution and displacement. Multiple iliac-bone grafts were placed medially and anteriorly about the fracture site.

Following operation, skeletal Russell traction was continued. The wound healed by primary intention without evidence of systemic or local infection. Fifty-four days after open reduction, traction was discontinued, and the patient began to walk with crutches without bearing weight on the right. At discharge on April 15, the patient's general condition was good, the wound was well healed, and the fracture showed early bone union which was not sufficient for weight-bearing (Fig. 2). Despite the absence of symptoms, roentgenograms made on May 10 and on July 12 (Fig. 3), showed a break in two screws. There was also evidence in the films that the other screws were slightly loose. Six months after operation, examination revealed good motion of the right hip. The operative wound was well healed. Roentgenographic examination indicated slight sclerosis of the large proximal cortical fragment and slight delay in union on the lateral aspect of the femur which was thought to be a result not only of the comminuted nature of the fracture, but also of the avascularity of the fragment. Union was progressing well on the medial aspect of the femur. The patient was allowed to place half of her weight on the extremity, using crutches.

Eight and one-half months after operation, the patient was much more active. The extremity had shortened approximately five-eighths of an inch. Hip and knee motion was excellent. Roentgenograms showed further healing of the fracture with no change in the position of the fragments. There was suggestive evidence of motion of the Smith-Petersen nail.

* This research was supported in part by a grant from the National Institutes of Health, United States Public Health Service, RG-4251

FIG. 1

FIG. 2

Fig. 1: Roentgenogram of fracture made on admission showing multiple fragments and involvement of intertrochanteric, trochanteric, and diaphyseal parts of the femur.

Fig. 2: Roentgenogram of fracture made February 17, 1955. The position is essentially as it was postoperatively. There is a slight bend in screw *F* and slight resorption of cortical bone at the medial extremities of screws *B*, *F*, *G*, and *H*. Callus is present at the lesser trochanter, and there is slightly increased density of the lateral cortical fragments of the femur.

The degree of weight-bearing was increased. Eleven months after operation, the patient was walking with a cane and was doing light housekeeping. Roentgenograms showed progressive union of the fracture. Considering the magnitude of the fracture, the result was considered excellent at this time. Sixteen months after operation, the patient had no complaints and was performing normal activities. The wound was well healed. Roentgenograms showed excellent position and solid union of the fracture. They also showed that the nail was loose and that reaction was present around the screws. The patient was bearing full weight with and without the use of a cane. She was advised to return if any untoward symptoms appeared. Removal of the internal fixation appliance was considered but was not urged because of the absence of symptoms, the lack of local reaction in the wound, and the medical risk of another operative procedure.

The patient was admitted to another hospital on May 17, 1957, twenty-nine months after fracture, for treatment of a firm tender swelling of two weeks' duration on the posterior aspect of the right thigh. The swelling had become larger and more painful, but the patient's general condition was good and there was no history of fever. The swelling was incised and 250 cubic centimeters of cloudy serosanguinous pus was evacuated. No organisms could be cultured from this material.

The patient returned on October 14, 1957, because of persistent drainage from a sinus at the site of surgical drainage. Physical examination showed a draining sinus surrounded by a small zone of cellulitis on the posterior aspect of the thigh. The scanty yellow serous discharge yielded *Staphylococcus aureus*, coagulase positive. The right hip again showed excellent painless motion and solid union of the fracture. No new medical diagnoses were evident at this time. Roentgenograms revealed no essential change in the right hip compared with those made seventeen months earlier. The sinus tract of the right thigh was injected with an opaque medium and roentgenograms showed continuity of the sinus and the region of the Thornton plate and fracture site (Fig. 4).

On October 17, the original operative wound was reopened and considerable replacement of the vastus lateralis by fibrofatty tissue was evident. The sinus tract entered the lower part of the wound. The Thornton plate was surrounded by a heavily scarred wall lined with brownish granulation tissue and covered with cloudy yellow serous exudate. The plate

assembly could be moved slightly in all directions. All of the screws in the plate were loose in the bone and turned easily although the threads were still holding. The plate and nail were removed as a unit since that part of the assembly was securely fastened. A portion of one of the broken screws was not removed, since it was covered with bone. Except for the shaft of this one screw, all of the metallic items used for internal fixation were recovered at this operation. Inspection of the fracture site revealed solid bone union in good position. A polyethylene tube was inserted for irrigation, and the wound was closed. The sinus tract was left open for possible drainage. Microscopically, the tissue surrounding the bone plate showed chronic inflammation, granulation tissue, considerable brown staining pigment which stained positively for iron, and foreign-body giant-cell reaction.

FIG. 3

FIG. 4

Fig. 3: Roentgenogram of fracture made July 12, 1955. Screw *D* has broken at the plate margin. Screw *F* has broken near the lateral cortex. Resorption has begun at the lateral cortical screw holes. There is increased callus medially. The density of the lateral cortical fragment is decreased.

Fig. 4: Roentgenogram of fracture made October 15, 1957. The fracture is well healed. The opaque medium, injected from below, is seen in the vicinity of the lower and upper parts of the Thornton plate. The screw head from screw *D* is near screw *A*, that of screw *F* is lateral to the plate. Bone resorption is evident distal to the Smith-Petersen nail and near several of the screws.

During the operation, one episode of hypotension occurred, but the patient appeared to be in good condition upon completion of the procedure. About six hours after the operation, she suddenly became hypertensive and febrile. The hypertension lasted for about one-half of an hour. The patient remained unresponsive. Eighteen hours after operation, she could not move the left upper and lower extremities. A positive Babinski reflex was present on the left, and left facial palsy was evident. An electrocardiogram indicated acute myocardial infarction. The patient died on the fourth day after operation.

Necropsy revealed acute myocardial infarction as the cause of death. Additional findings were myocardial hypertrophy; severe arteriosclerosis and calcification of coronary arteries, brain vessels, aorta, and main branches; severe arteriosclerosis of the vessels of the pancreas, kidneys and adrenal glands; recent microscopic hemorrhage of the right internal capsule; small cyst, probably representing old hemorrhage in the left internal capsule, right internal capsule, left thalmus, and right temporal lobe; acute peptic ulcer, 0.3 centimeter in diameter; recent infarcts in the spleen; and healed fracture of the right femur, with marked fibrosis, chronic inflammation, and large collections of iron-containing pigment in macrophages and extracellularly (rust granuloma).

THE METALLIC SPECIMENS

The Smith-Petersen nail, Thornton plate, and bolt were disassembled. The screws were labeled *A* to *H* according to their placement, *A* having been in the most proximal portion of the appliance (Fig. 5). The metallic items were then washed in soap and water, and the clots were removed with the aid of a cloth and a soft nylon brush. Each item was examined under the dissecting microscope; its magnetic attraction was then tested with a small Alnico magnet. The general composition of each item was first identified by rapid spot-testing procedures [10], followed by analyses for chromium, nickel, and iron by colorimetric methods [1,8]. Spectrographic analyses were performed in several instances by the use of a Jarrell Ash grating with a plate factor of 10.9 Angström units per millimeter in the first order and 5.45 Angström units per millimeter in the second order and by the use of a high-voltage spark with pre-exposure sparking time of ten seconds and exposure time of fifteen to thirty seconds. These were supplemented by fluorescent x-ray analysis.*

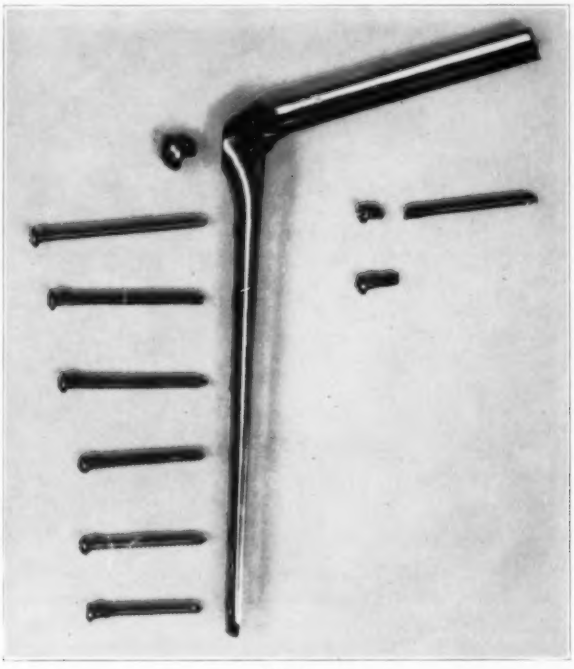


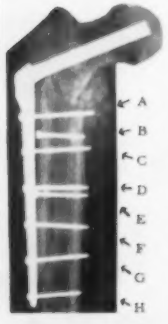
FIG. 5

The metallic items as removed and disassembled, before washing. Screws *D* and *F* are on the right. Screws *B* and *E* are just above screw *H* at bottom left. Screws *C* and *G* show a slight bend. Most of the discoloration of these screws is clot, but some tarnish is also evident.

Areas of corrosion were examined microscopically before and after rapid etching with acid. No measurements of tensile strength were attempted. From fabricators of the Smith-Petersen nail and of the Thornton plate and bolt the specifications concerning their composition were obtained. Since the screws had come from the central surgical supply of the Clinic, where all stainless-steel screws were stored together, the fabricators of the individual screws could not be identi-

* Chemical analyses supervised by Dr. Truman J. Licht, Boston College, and fluorescent x-ray analysis was done by Dr. Kenneth J. Tauer, United States Army, Watertown Arsenal.

fied. Correspondence with the companies which manufactured the nail and plate, and later personal discussion with representatives, revealed that the specifications for composition of the nail had changed from AISI type 303 to AISI type 316 during the interval 1954 to 1958, but that the plate specifications had remained those of AISI type 303. The degree of correspondence of specifications to actual composition will be noted in Table I. Parenthetically, it may be added that the specifications for chemical composition, furnished by the appliance manufacturers, were those given them by the producer of the stainless steel to indicate compliance with specifications. No check analyses were made by both of the companies in question of the metal as received.



	HEAD	LENGTH	DIAMETER	THREADING	THREADS
A	Round	1 7/8	0.44"	Machine, full depth	32/"
B	Round	1 3/8	0.136"	Machine, full depth	20/"
C	Round	1 5/8	0.14"	Machine, full depth	32/"
D	Round	1 5/8	0.14"	Machine, full depth	32/"
E	Round	1 3/8	0.136"	Machine, full depth	20/"
F	Round	?	0.14"	Machine, full depth	32/"
G	Round	1 5/8	0.14"	Machine, full depth	32/"
H	Oval	1 1/4	0.136"	Shallow cut	20/"

TABLE I

FIG. 6-A

FIG. 6-B

The bolt which attached the Smith-Petersen nail to the Thornton plate. The threads are markedly corroded (Fig. 6-A) and the end (Fig. 6-B) pitted. The bolt head is shiny.

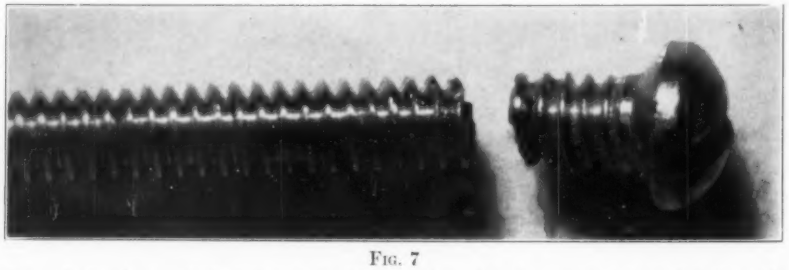


FIG. 7

Screw *D* showing marked pitting in the fifth and sixth thread grooves. A large hole is evident on the right side of the ninth grove.

RESULTS

Two principal sites of corrosion were evident: the bolt shaft and tip (Figs. 6-A and 6-B), and the shaft of the bone screw *D* (Fig. 7). The bolt showed a marked loss of substance at the threaded portion, particularly in the mid-shaft, and a pitted appearance in the terminal portion. The outer surfaces of the bolt head and slot, and the flat undersurface of the bolt head, did not show a gross loss of substance although the sheen was dulled. A slight scoring of the slot had been caused by screwdriver slippage. Rust had accumulated at the junction of nail and plate (Fig. 8-A), and in the nail socket (Fig. 8-B). When these rust accumulations were removed, the surfaces of the nail and plate did not show significant loss of substance or intensified discoloration.

The physical descriptions of the screws are found in Table I. All were of the Sherman type with single slot and self-tapping tip.

The broken screw *D* (Fig. 7) showed marked pitting at its fracture site. The pitting had occurred only in that part of the shaft from the third to the ninth threads and involved six grooves of the screw on one side only. The pits extended

FIG. 8-A

FIG. 8-B

Junction of nail and plate (Fig. 8-A) and bolt socket (junction of plate and nail) (Fig. 8-B) to show accumulation of rust.

into the substance of the screw about one third of its diameter and were particularly deep at the fracture site. They were filled with a grey, granular mass. The surface of the screw was dull grey. When the screwhead was fully inserted into the plate (screwhead countersunk), the thickness of the plate covered three threads of the screw, that is, nearly all of the corroded portion of the screw was at some distance from the plate.

The broken screw *F* showed a sheared surface which had the same general tarnish as that seen on the head and shaft, but no pitting. Screws *A*, *C*, *F*, and *G* showed an over-all loss of brightness and thin, dark grey tarnish which could be abraded with ease by emery paper, leaving a bright surface. All had screwdriver marks and, where there was contact with the plate, areas of erosion (but not corrosion) at the undersurface of the head and adjoining threads. These areas of erosion were brighter than the surrounding tarnished surface, and no rust was found in relation to them. Two of the screws (*C* and *G*) showed a very slight bend in the mid-portion. Concerning tarnish and markings, screw *H* differed but little from those already described. The tarnish was slightly lighter, and the driver marks and plate erosion marks slightly less prominent. The two screws

which fixed the free fragment to the remainder of the femur (*B* and *E*) were of yet another type, and showed decidedly less tarnish than the other screws, but also had pronounced driver marks in the slots. No evidence of rusting was found on these screws.

The outer and inner surfaces of the Thornton plate were bright and shiny including the areas of slight scratching near the screw holes, but the surfaces of the screw holes were a dull grey. Except for the rust accumulation already described, there was no sign of corrosion on the plate; when the accumulation was removed, the metal uncovered was shiny and untarnished.

The surface sheen of the Smith-Petersen nail was slightly dull, but except for the corrosion found at the threading of the bolt socket, there were no localized areas of corrosion on it. The metal where the manufacturer's labels had been stamped was intact. The corrosion of the bolt socket was similar in all ways to that described for the bolt. The area of corrosion was deep in the socket and did not involve the four threads nearest the bolt head.

Results of the chemical analyses of the various parts are indicated in Table II.

TABLE II

PER CENT COMPOSITION OF METALLIC COMPONENTS

Item	Cr	Ni	Mo*	Magnetic Permeability	Probable Type
Screw A	18.16	8.85	—	++	303
Screw B	18.44	10.3	+++	0	316
Screw C	18.31	9.25	—	++	303
Screw D	17.53	9.01	—	++	303
Screw E	18.00	9.81	+++	0	316
Screw F	18.51	8.91	—	++	303
Screw G—lost				++	
Screw H	18.37	9.18	—	0	303
Bolt	17.63	8.90	0	+	303
Nail	17.89	9.29	0	0	303
Plate	17.46	8.70	—	+	303
AISI 303 specification	17-19	8-10	0.6 max.	+ or 0	
AISI 316 specification	16-18	10-14	2-3	+ or 0	

* Positives refer to intense spot test; negatives to negative spot test; and zeros to negative spot and spectrographic tests.

DISCUSSION

The clinical aspects of this case need little comment. The immobilization and alignment achieved by the appliance in the first few weeks of treatment resulted in healing of the fracture and clinical success, despite subsequent loosening of the screws and slight migration of the Smith-Petersen nail. The sterile abscess which appeared twenty-eight months after operation resulted from the chronic irritative properties of the corrosion products, as confirmed by the rust granuloma found at necropsy. The metal undoubtedly should have been removed at the time the swelling appeared in the thigh, instead of simple incision and drainage. It seems probable that the subsequent secondary infection and the third operation, five months later, proved fatal to the patient.

The metallurgical aspects of this case require a good deal of attention. From the mechanical point of view, the fixation of the fracture, although considered adequate, was not ideal. The screws were not exactly parallel, and at least one was demonstrably bent. However, the most likely explanation for the breaking of two screws at about the sixth postoperative month, not preceded by evidence of loosening of screws and not caused by known increase in stress (trauma or weight-bearing), is the corrosion of one screw during the sixth-month interval.

It may be postulated that the screw was so weakened that it broke, thereby increasing the load on the bent screw which also broke, although the latter was not demonstrably weakened by corrosion. The other screws probably were sufficiently loose to adapt to the new mechanical pattern since later roentgenograms showed bone resorption around them.

The mechanical considerations fade into relative insignificance before the salient feature of the foreign-body reaction. This undoubtedly was caused by the products of corrosion. So-called reaction to metallic implants may occur because of mechanical as well as chemical stimuli, but the intimate association of rust particles with the inflammation in this instance provides good evidence that the corrosion products were at least one important factor in its causation. The mere presence of scarring, chronic inflammation, and corrosion is not sufficient to label any single case as a clinical failure since many successful cases have had these processes manifest to some degree. Their excessive extent in this case however is sufficient evidence to incriminate them.

The data presented illustrate a few of the characteristic ways that corrosion occurs in stainless steel. Recent medical literature has not considered in detail the application of newer metallurgical knowledge of corrosion to the surgical uses of stainless-steel implants. Most articles not only fail to characterize instances of corrosion by adequate description, but attribute them uniformly to electrolysis; this is not a meaningful explanation, since every chemical reaction is essentially electrochemical. If the term *electrolysis* is used in its restricted sense, that is, the reaction of two different metal electrodes placed in a solution of an electrolyte, the term then can be applied to few, if any, clinical instances of corrosion.

The limitation of space will confine the discussion of corrosion mechanisms to the various types of corrosion that must be considered in this particular case.

The over-all tarnish of the screws may be related to their lesser corrosion resistance as compared with plate and nail. The chemical composition of the screws, that is, their low content of chromium (at the low limit of specification for the steel type), may be held responsible for this generalized process, which resembles the oxidative reactions of most steels to a fluid environment containing electrolytes and dissolved oxygen. The absence of generalized rusting is also characteristic of some stainless steels in similar environments at nearly neutral pH. Since corrosion may be defined as "the destruction of a metal by a chemical or electrochemical reaction with its environment," the generalized tarnish must be considered corrosive. This reaction was not progressive in its dissolution of metal, however, and may have protected the metal from further loss. Although a number of different steel alloys were used in this instance, and differences in their degree of tarnish were evident, the tissue reaction was probably not related to these different degrees of oxidation. Tarnish of this type is not a progressive dissolution of metal.

No evidence of corrosion resulting from galvanic currents between dissimilar metals was evident in this case. Such evidence would be the localized loss of metal from the less noble of the two metallic items at those portions of their surfaces which were in contact. The areas of contact of the metallic items of different composition were not the sites of the most corrosion. Only one area of contact of items—the bolt thread and nail socket—showed significant corrosion and these two items had the same general composition. However, the possibility of galvanic corrosion cannot be dismissed only on grounds of its absence at areas of contact of different metals, although this is strong negative evidence. Galvanic corrosion is possible wherever metals of different composition are used, but the limits of variation of the composition which permits galvanic corrosion have not been clearly shown, particularly for stainless steel.

LaQue [6,7] has shown that where galvanic corrosion occurs, its magnitude is

Intergranular corrosion, as exemplified in the broken screw in the discussion

not related quantitatively to the positions of the metallic elements in the *electromotive* series or of metallic elements or alloys in experimentally obtained *galvanic* series. He emphasized that positions of metallic elements or alloys in a galvanic series depend greatly on the medium in which the metals are experimentally tested. Different test conditions will lead to different orders of placement of alloys or metals in relation to one another and the order of placement may have no relation to the amount of corrosion encountered. Wesley showed that the important factors were those influencing the polarization of different areas on metal under the conditions of the experimental or practical situation; these factors were controlling with respect to the degree of corrosion of galvanic type. Uhlig defines polarization as the production of counter EMF by products formed during or by concentration changes resulting from the passage of current through an electrolytic cell. Obviously continued galvanic corrosion depends on continued depolarization of the anode or cathode, for example by removal of impermeable corrosion products and continual breaking of passivated film. LaQue's experimental galvanic series, for which sea water was used as the medium, revealed the interesting and pertinent fact that stainless steels as a class exhibited erratic behavior with regard to their position in the series. The potential for an 18-8 type varied from 0.08 volt to 0.53 volt, both determined with respect to a saturated calomel half-cell. This means that different items of the same stainless steel may act as the poles of a circuit leading to electrolytic (galvanic) corrosion. While this process may have been operative on a microscopic order of magnitude in the present case, grossly, most of the corrosion described cannot be ascribed to galvanic-corrosion reactions and thus to the diverse alloys used.

Pitting corrosion is well illustrated in this case by the bolt. This type of corrosion is particularly common in the stainless steels and its occurrence at a single site demonstrates the principle underlying its localization. This principle is the production of either an oxygen cell or a metal concentration cell, probably the former. The influence of dissolved oxygen on the rate of corrosion in media containing electrolytes is well known. When a single piece of metal is exposed in two areas of its surface to two different concentrations of dissolved oxygen in the environment, the stage is set for production of the oxygen cell. This consists in the assumption of cathodic properties by that area of metal exposed to the higher concentration of oxygen and the assumption of anodic properties by that portion of metal exposed to the lesser concentration. The reason for this phenomenon is the action of oxygen as a hydrogen acceptor in the electrolyte solution. A dissolution of metal from the anodic portion then occurs and continues as long as the gradient in oxygen concentration exists or until the cell is polarized by the growing concentration of metallic ions in the solution adjacent to the anode. The formation of a metal concentration cell is analogous to that of the oxygen concentration cell but in reverse (that is, in reference to concentration of metallic ions as opposed to oxygen in solution). Where the concentration of metallic ions in the solution differs from one area to another, that area of metal in contact with the higher concentration of metallic ions becomes the cathode and that in contact with the lower concentration becomes the anode. Thus the formation of the metal concentration cell tends to counterbalance the oxygen concentration cell in action. In this particular case, the setting for a differential oxygen concentration was present in relation to the bolt and nail socket. It may be postulated that the slight film of tissue fluid in contact with the bolt at its tip was not circulating or exchanging at any great rate with the tissue fluids in contact with the remainder of the metallic device. Since tissue fluids can be shown to contain dissolved oxygen at a tension only slightly lower than atmospheric, the stasis and resulting consumption of the small amount of oxygen in the tissue fluid at the bolt socket could well have led to the formation of an oxygen cell. Once this had occurred, the process of pitting would continue until the concentration of metal ions in that fluid was sufficiently high to reverse the polarity of the cell.

Intergranular corrosion, as exemplified in the broken screw, is the dissolution of metal which occurs selectively at the boundaries of grains in the metal. The theory has been that it occurs as a result of the formation of chromium carbides in those areas, with consequent impoverishment of adjacent metal with regard to chromium. Maintenance of corrosion resistance depends *inter alia* on an adequate chromium concentration *in all areas*. An average concentration for a large sample which is not sufficiently above that level may not protect against critical impoverishment at the grain boundaries. The resulting dissolution of metal at grain boundaries separates granules of unrusted metal. In this case, the granules found within the extensive pits demonstrate this phenomenon. The chromium content of the screw, while within specifications for 303 steel, undoubtedly was too low for adequate corrosion resistance.

The magnetic properties of the screws and the plate are evidence of the presence of non-austenitic phases in the metals composing them. The formation of martensitic or ferritic components in stainless steel indicated a composition of the screw with regard to carbon, chromium, and nickel which prejudices it against maintaining the austenitic state throughout. Those stainless steels that are most resistant to corrosion in media most resembling tissue fluids are austenitic. Since ferritic and martensitic stainless steels are more prone to pitting and intergranular corrosion, the finding of magnetic properties confirms the chemical analysis in indicating decreased corrosion resistance.

While an explanation of the structure of the phases present in stainless steel would take this discussion too far afield, some indications of the significance of the crude test of magnetic permeability may be permitted because of its obvious utility and appeal as a simple and non-destructive test. Steels attract a magnet (that is, have increased magnetic permeability) when some portion of the steel is in the ferritic state. The 18-8 steels (a term usually designating types 302, 303, 304, and 308 and others which contain chromium and nickel in the approximate ratio of 18 to 8 per cent) and the 18-8 Mo (including types 316 and 317) were designed primarily to remain completely austenitic, that is, without ferrite. When the composition is such that the elements predisposing to ferrite (principally carbon, chromium, and molybdenum) are not balanced by an adequate concentration of those predisposing to austenite, principally nickel, ferrite formation may occur. The more ferrite present, the more magnetic the steel. A precarious balance of the concentrations of elements may be tipped toward production of ferrite, especially by excessive cold working of the steel during fabrication, but also by improper heat treatments. An increased magnetic permeability of these special stainless steels, therefore, may indicate imbalance in original composition or excessive working of the metal, but in either case, decreased corrosion resistance. It is evident from the chromium and nickel content of the screws that this may have been the case.

Thus three types of corrosion were present in this case, which we may categorize as chemical, pitting, and intergranular. Galvanic corrosion was not evident nor was stress corrosion. The latter, which refers to accelerated dissolution of metal in areas of cyclical stress, cannot be eliminated as a possibility. For evidence that might implicate stress corrosion however, the areas of concentration of stress and the intensity of the stress at each point in the various components of the fixation apparatus would have to be determined—a task not possible at this time.

The investigation of this case from the metallurgical point of view might have been extended to include other important determinations. Among those are the Brinell or other test of hardness, tensile or other tests of strength, degree of grain, and chemical determinations of the concentrations of the other elements in the samples. Facilities for these determinations were not available. However, the types of corrosion seen in this case are adequately explained or indicated by the

data obtained. Other cases of breakage or corrosion of metallic implants may require some or all of the determinations mentioned and perhaps additional ones, before they can be explained reasonably.

It may be asked what measures could have been taken to avoid this failure. From the point of view of the operating room supervisor or surgeon, close supervision of materials must obviously be considered, in procurement, proper identification, and proper storage of metallic implants. The criteria to be followed for the establishment of specifications are not clearly indicated as yet, and much experimental work must be done before specific principles can be laid down to supplement the surgeon's judgement. From the point of view of the fabricator of surgical materials, certainly conformity to the specifications established for the items in question should be stringently regulated. What those specifications should be also depends to a large degree on judgment, and much more experimental work is needed to delineate the principles regulating specifications.

Finally, the role of testing should be emphasized. LaQue has pointed out that metallurgical tests for corrosion are valuable, but no test or group of tests gives results which correspond exactly to the performance of materials in service. No set of test conditions can duplicate exactly the condition of service. In the surgical experiment, to borrow the phrase of Barr, a large number of factors affecting corrosion resistance are present in unknown degree. The composition of tissue fluid with respect to dissolved oxygen, electrolytes, and corrosion inhibitors, the localized and generalized variation in this composition, the amounts and locations of stress, are examples of such factors. Modern knowledge of corrosion extends far beyond the simple theories elaborated by Venable and Stuck, and beyond the experimental data of Fink and Smatko, in which weight loss was the sole criterion of corrosion. Many of the present-day specifications and practices in fabrication of metallic appliances for internal application are based on the now outmoded work of these investigators.

It is apparent that corrosion testing conditions appropriate to the surgical implant are difficult to devise. All such tests are of limited value in predicting the performance of specific materials. What the in-service test is to industry, the clinical case is to surgery—the final criterion of the adequacy of a material. When materials have failed in clinical use, they provide invaluable opportunities for investigation and prevention of future failures. Only by such investigation, correlated with experimentation, can the reasons for failures be understood and avoided.

REFERENCES

1. American Society for Testing Materials: Methods of Chemical Analyses of Metals, pp. 105-107. Philadelphia, 1950.
2. Cater, W. H., and Hicks, J. H.: The Recent History of Corrosion in Metal Used for Internal Fixation. Lancet, **2**: 871-873, 1956.
3. Curry, G. J., and Pine, D. K.: Deficiencies of Stainless Steel Internal Fixation Units. Am. J. Surg., **95**: 518-523, 1958.
4. Fink, C. G., and Smatko, J. S.: Bone Fixation and the Corrosion Resistance of Stainless Steels to the Fluids of the Human Body. J. Electrochem. Soc., **94**: 271-277, 1948.
5. Kulowski, J.: Hip Nail Corrosion. U.S. Armed Forces Med. J., **1**: 654-660, 1950.
6. LaQue, F. L.: Corrosion Testing. Proc. Am. Soc. Testing Materials, **51**: 495-582, 1951.
7. LaQue, F. L., and Cox, G. L.: Some Observations of the Potentials of Metals and Alloys in Sea Water. Proc. Am. Soc. Testing Materials, **40**: 670-689, 1940.
8. Makepeace, G. R., and Craft, G. R.: Colorimetric Determination of Nickel in Steel. Ind. and Eng. Chem., **16**: 375-377, 1944.
9. Marshall, D. V.: Three-Side Plate Fixation for Fractures of the Femoral and Tibial Shafts. J. Bone and Joint Surg., **40-A**: 323-345, Apr. 1958.
10. Miller, H. W.: Spot Identification of Stainless Steels. Metals and Alloys, **21**: 1364-1366, 1945.
11. Uhlig, H. H.: The Corrosion Handbook, p. 30. New York, John Wiley and Sons, 1948.
12. Venable, C. S., and Stuck, W. G.: Internal Fixation of Fractures. Springfield, Illinois, Charles C. Thomas, 1947.
13. Wesley, W. A.: Controlling Factors in Galvanic Corrosion. Proc. Am. Soc. Testing Materials, **40**: 690-704, 1940.
14. Zapffe, C. A.: Human Body Fluids Affect Stainless Steel. Metal Progr., **68**: 95-98, 1955.

A Radioisotopic Investigation of the Contamination of Screws and Tissues by Screwdrivers

A Study in Applied Metallurgy *

BY P. G. LAING, M.B., F.R.C.S., LAVERNE R. MADANCY, B.S., AND MARY A. GREBNER, B.A., PITTSBURGH, PENNSYLVANIA

From the Orthopaedic Department and Addison Gibson Laboratory, University of Pittsburgh, Pittsburgh

It has been shown previously that screwdrivers used in orthopaedic surgery contaminate inserted screws by a process of metal transfer [2,3,4,5,6,10]. Opposing metal surfaces do not come into contact over their entire areas. Even highly polished metal surfaces have projections of metal crystals which may be quite high, metallurgically speaking. When two such surfaces are brought into contact it has been described as similar to inverting one range of mountains on another, having only the peaks touching. In metal-to-metal contact, the entire pressure is borne at these small points of contact which may be less than 1/10,000 part of the apparent surface area. Thus, the great pressure at these points unites the metal peaks by the process of cold welding. When the two pieces of metal are separated, the welded joints remain firm, the metal projections fracture beyond the area of work hardening, and pieces of each remain welded to the other [1].

This can be demonstrated by radioactivating the screwdriver and then, after handling the screw, taking counts and making autoradiographs of the screw heads [6]. The seeding of the surface of an implant with many small pieces of metal of a different alloy or one in a different metallurgical condition is tantamount to the insertion of mixed metals. This may be a potent source of corrosion and may lead to failure of the operation [6,8,9] because of electrolytic inflammation, loosening of the implant, or failure of the bone graft. Previous work [10] has shown that the tissue reaction around buried screws varies with the type of screwdriver used. The weight changes of such handled screws buried in the back muscles of rabbits have been studied. A screwdriver made of AISI 420 stainless steel appeared suitable for both AISI 316 and cobalt-chromium-molybdenum screws. It was speculated that a screwdriver made of cobalt-chromium-molybdenum alloy might be more satisfactory for screws made of this alloy.

This experiment was designed to investigate the amount of metal transfer between simple screwdrivers made of several alloys and orthopaedic screws of four alloys or elements. Radioisotopic techniques similar to those previously described by Bowden, Williamson, and Laing [6] were planned. The fundamental idea was to test each screwdriver with screws made of the commonly used inert metals. Much time and energy has been devoted to the development of inert metals used to make implants. Obviously, it is essential to preserve this inertness, by any means, during implantation.

METHOD

Five small, simple, screwdriver bits, each one-inch long and one-quarter of an inch in diameter, were manufactured of the following metals: (1) tool steel (low chrome); (2) AISI 410 stainless steel; (3) AISI 420 stainless steel; (4) AISI 316 stainless steel; and (5) cobalt-chromium-molybdenum alloy (Vitallium).

* This project was supported by United States Public Health Service Grant A 1625.

TABLE I

SPECIFICATIONS OF MATERIALS USED FOR THE MANUFACTURE OF SCREWS AND SCREWDRIVERS

	C	Cr	Ni	Mo	Co	W	Ti	Si	S	P	Fe	Mn	
AISI 316	.08	17-20	10-14	4				.75	.03	.03	65	2	
AISI 410	.15	11.5-13.5						1.0			84	1	
AISI 420	.3	12-14	.31					1.0	.03	.04	84	.47	
Carpenter Solar Tool Steel	.5	.1	.13	.5				1.0	.03	.03	97	.4	V .25
Co-Cr-Mo (Vitallium)		30		3	65			Tr			.7-1	Tr	
Haynes 25 (Neutrilium)	.05 .15	19-21	9-11		46-53	14-16		1.0	.03	.04	1.8	1.2	
Titanium	.03						99				.25		N .04

The bases of these small bits were marked so they could be distinguished after irradiation. The samples were then irradiated in the neutron flux at Oak Ridge National Laboratory until each had acquired an activity of about 1.5 millicuries.

Coarsely threaded self-tapping orthopaedic screws were obtained made of the following metals: (1) AISI 316 stainless steel, electropolished and passivated; (2) cobalt-chromium-molybdenum alloy (Vitallium); (3) commercially pure titanium (Rem-Cru A70); and (4) Haynes stellite alloy 25 (Neutrilium). The specifications of all metals used in this work are given in Table I.

Blocks of white pine were then prepared for the insertion of these screws by having holes, seven sixty-fourths of an inch in diameter, drilled through them. Three screws from each of the above groups were then driven into separate wooden blocks by each of the five screwdrivers. In each group of three screws the first was handled lightly, the second heavily, and the third more heavily. The amount of slippage of the driver in the screw slot was also deliberately increased each time. The small driver bits were held in a universal handle so designed that the radioactivated driver bits did not have to be touched by hand during insertion or removal. Since the wood used for the blocks was considerably softer than bone, the force needed to drive in each screw was considerably less than that usually needed when dealing with hard cortical bone. It approximated that needed for cancellous bone. Particles emitted from each screw head, now flush with wood, were then counted from a fixed distance by a shielded scintillation counter. The γ-radiation only was counted with the wooden block placed on its side in front of the tube center. This point is important in considering the results.

Autoradiographs were then prepared by placing the wooden blocks on Kodak no-screen x-ray film with the screw heads in contact with the paper covering the film. Exposure time was two weeks, then the films were developed in the usual manner.

A decay curve was plotted for each driver bit by counting the radiation forty-eight inches away through a two-inch aluminum screen. This was done several times from the time of the handling of the screws during a six-week period.

At this stage the driver bits were dissolved in concentrated hydrochloric acid and nitric acid by a member of the staff of Crucible Steel Research Laboratories. The resultant solutions were then diluted to a suitable degree calculated to give 200 micrograms of metal per milliliter of solution. One milliliter of each solution was dried on a metal planchet and counted under the same conditions as had been the screw heads. Knowing the weight of metal per milliliter of solution, we calculated the activity per microgram of the driver metals at the time of their going into solution and then corrected for decay. This gave the activity per microgram of each screwdriver bit at the time of the handling of the screw.

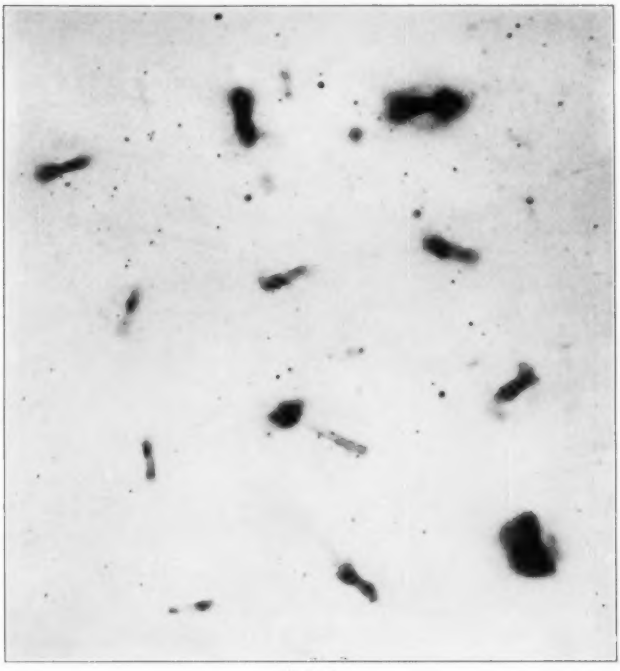


FIG. 1

Autoradiographs of the screw heads showing metallic transfer from the radioactive tool-steel screwdriver (Table II). Cobalt-chromium-molybdenum screws are on the top row; the second row, AISI 316; the third row, titanium; and on the bottom, Haynes 25. The amount of pressure used increases from left to right.

METAL CONTAMINATION OTHER THAN TRANSFER

During counting of the radiation from the screw heads, it became evident that radioactive material was falling onto the bench area in front of the counting tube. Inspection and monitoring of the bench revealed that large flakes of intensely radioactive metal which had obviously fallen off the screw heads and had originally come from the radioactive drivers were lying there. The handling of the screws had been performed in another room so that the contamination of the bench could only have come from the minute fragments which fell off the blocks when they were turned on their sides for counting purposes.

A second series consisting of eleven of each of two types of screw, AISI 316 and cobalt-chromium-molybdenum alloy (Vitallium), was then heavily handled with all five drivers. Two screws were handled by each driver except for three handled with the AISI 420 driver. This time great care was taken to seal the top of the screw and the adjacent wooden block with plastic paint immediately after handling in order to trap all metal flakes from the drivers and to prevent their dropping off when the blocks were placed on their sides for counting.

Counts were made in the manner previously described. Autoradiographs were made from this second series of screws and the weight of both transferred and flaked metal calculated as described.

RESULTS

The outstanding result was, of course, the discovery that there are two ways in which an inherently inert orthopaedic screw may be contaminated by the screwdriver used to insert it. First, there is the metallic transfer previously de-

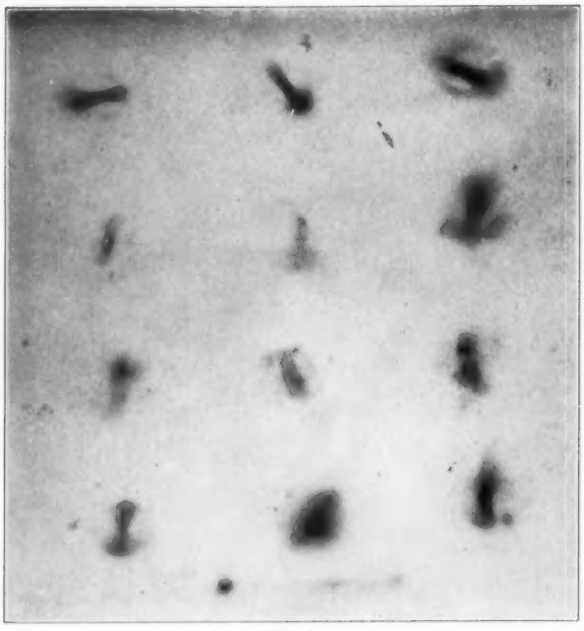


FIG. 2

Autoradiographs of the screw heads showing metallic transfer from radioactive AISI 316 screwdrivers (Table III). Cobalt-chromium-molybdenum screws are on the top row; the second row, AISI 316; the third row, titanium; and on the bottom, Haynes 25. The amount of pressure used increases from left to right.

scribed, whereby many ultramicroscopic particles of the screwdriver are left welded onto the screw head. Second, there are large particles cut off the driver near the hard, screw slot edge and then left lying in the wound on or around the plate and screws. Since the drivers are of a different composition and in a different metallurgical condition from the implants, corrosion may be started by the well known battery effect with the passage of an electric current between the two dissimilar metals and the production of electrolytic osteitis [10,11].

The details of the amounts of metal transferred from the five screwdrivers to the four types of screw under slight, medium, and heavy pressure and slippage are given in Tables II through VI (Figs. 1 through 5). The amounts of metal transferred to the second series of screw heads, over which we spread a sealing layer of plastic after handling, are given in Tables VII and VIII (Figs. 6 and 7). The results show a wide variation in the amounts of metal transferred in the different groups. This is probably accounted for by the varying amounts of slip in the contact of each driver with the screw. The results must be considered a demonstration of what may happen when a screw is placed in bone. Deductions made from the results are merely indicative; they are not statistically proved.

DISCUSSION

The calculations arrived at of the amounts in micrograms of transferred metal are subject to a considerable experimental error, probably near ±10 to 15 per cent [6]. For example, a value of 100 micrograms could be ninety or 110; one of one microgram, 1.1 or .9 per cent. It has previously been shown by Bowden, Williamson, and Laing [6] that an increase in transfer occurs with an increase of slipping of the driver in the screw slot. At first sight the present results some-

TABLE II

METALLIC TRANSFER FROM A TOOL-STEEL SCREWDRIVER

Screws	Slight Slipping (*Micrograms*)	Medium Slipping (*Micrograms*)	Heavy Slipping (*Micrograms*)
Co-Cr-Mo (Vitallium)	22	38	14
AISI 316	19	4	3
Titanium	2	3	6
Haynes 25 (Neutrilium)	6	4	11

TABLE III

METALLIC TRANSFER FROM AN AISI 316 STAINLESS-STEEL SCREWDRIVER

Screws	Slight Slipping (*Micrograms*)	Medium Slipping (*Micrograms*)	Heavy Slipping (*Micrograms*)
Co-Cr-Mo (Vitallium)	24	45	96
AISI 316	8	13	91
Titanium	18	8	22
Haynes 25 (Neutrilium)	16	83	41

TABLE IV

METALLIC TRANSFER FROM AN AISI 420 STAINLESS-STEEL SCREWDRIVER

Screws	Slight Slipping (*Micrograms*)	Medium Slipping (*Micrograms*)	Heavy Slipping (*Micrograms*)
Co-Cr-Mo (Vitallium)	91	28	30
AISI 316	1	2	7
Titanium	3	3	3
Haynes 25 (Neutrilium)	2	6	9

TABLE V

METALLIC TRANSFER FROM AN AISI 410 STAINLESS-STEEL SCREWDRIVER

Screws	Slight Slipping (*Micrograms*)	Medium Slipping (*Micrograms*)	Heavy Slipping (*Micrograms*)
Co-Cr-Mo (Vitallium)	9	4	140
AISI 316	7	76	151
Titanium	8	13	11
Haynes 25 (Neutrilium)	3	20	28

TABLE VI

METALLIC TRANSFER FROM A COBALT-CHROMIUM-MOLYBDENUM (VITALLIUM) SCREWDRIVER

Screws	Slight Slipping (*Micrograms*)	Medium Slipping (*Micrograms*)	Heavy Slipping (*Micrograms*)
Co-Cr-Mo (Vitallium)	42	12	35
AISI 316	7	7	26
Titanium	20	8	5
Haynes 25 (Neutrilium)	7	31	15

TABLE VII

METALLIC TRANSFER FROM TOOL-STEEL, AISI 316, AND AISI 420 SCREWDRIVERS TO AISI 316 AND COBALT-CHROMIUM-MOLYBDENUM (VITALLIUM) SCREWS*

Screws	Screwdrivers		
	Tool Steel (*Micrograms*)	AISI 316 (*Micrograms*)	AISI 420 (*Micrograms*)
AISI 316	8	173	10
AISI 316	20	51	19
Co-Cr-Mo (Vitallium)	2	23	2
Co-Cr-Mo (Vitallium)	3	75	1

* The screw heads and wooden blocks had been covered with plastic immediately after handling in an attempt to trap some of the larger flakes of metal.

times seem to contradict this. Often more metal was found adherent to the screw slot with medium or slight slippage than with heavy. Even with a torque screwdriver, the force used and the amount of slipping in the slot are difficult to control.

However, during the course of the experiment a second variable factor, the flaking of visible pieces of the screwdriver against the screw slot, was noted. It must be remembered that the force required to drive the screws into soft wood is less than that used when dealing with hard cortical bone. This factor might

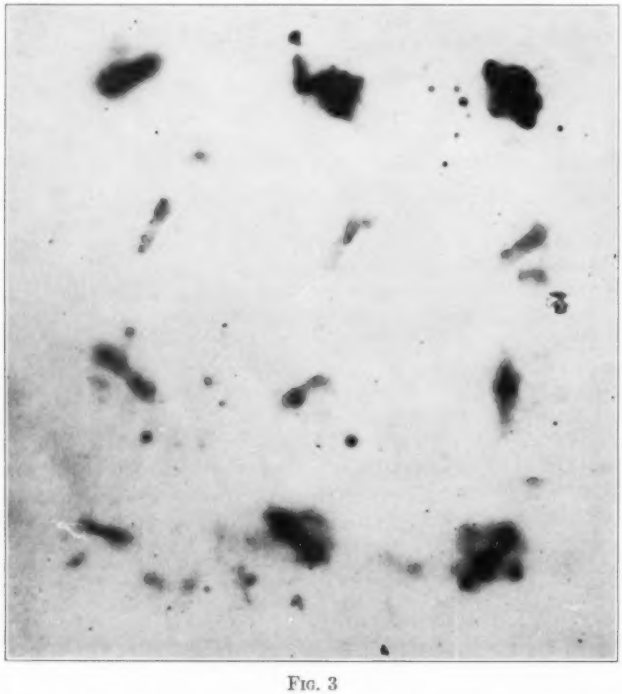


FIG. 3

Autoradiographs of the screw heads showing metallic transfer from radioactive AISI 420 screwdriver (Table IV). Cobalt-chromium-molybdenum screws are on the top row; the second row, AISI 316; the third row, titanium; and on the bottom, Haynes 25. The amount of pressure used increases from left to right.

TABLE VIII

METALLIC TRANSFER FROM AISI 420, AISI 410, AND COBALT-CHROMIUM-MOLYBDENUM (VITALLIUM) SCREWDRIVERS TO AISI 316 AND COBALT-CHROMIUM-MOLYBDENUM SCREWS*

	Screwdrivers		
Screws	AISI 420 (*Micrograms*)	AISI 410 (*Micrograms*)	Co-Cr-Mo (Vitallium) (*Micrograms*)
AISI 316		330	27
AISI 316	26	96	43
Co-Cr-Mo (Vitallium)	7	29	6
Co-Cr-Mo (Vitallium)		61	32

* The screw heads and wooden blocks had been covered with plastic immediately after handling in an attempt to trap some of the larger flakes of metal.

even be increased during surgery. When no attempt was made to seal these large fragments and the screw in its block was turned sideways for counting, a variable amount of debris dropped off and was found contaminating the work bench. Obviously, sometimes all the larger fragments, and sometimes only some, dropped off. Reference to the autoradiographs reveals hot spots both on the screw head and on the wood surface where these larger fragments adhered.

Correlation between the autoradiographs and the calculated amount of transferred metal was sometimes poor. The loss of metal particles from the screw slot and surrounding areas occurring when the blocks were transferred from the

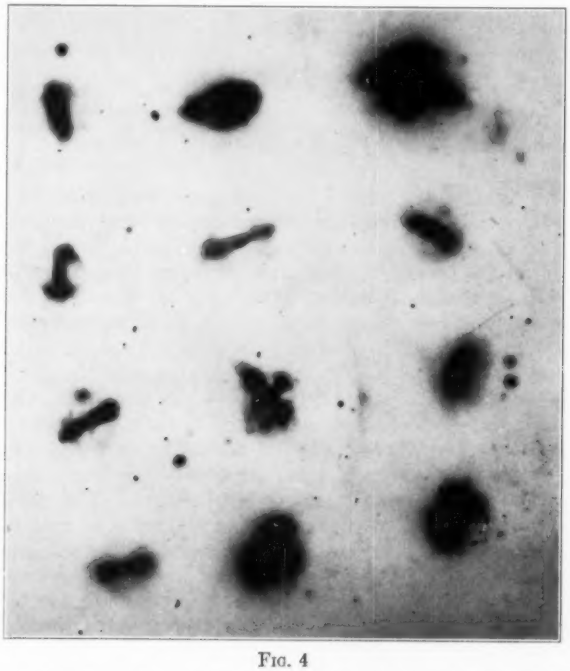


FIG. 4

Autoradiographs of the screw heads showing metallic transfer from the radioactive AISI 410 screwdriver (Table V). Cobalt-chromium-molybdenum screws are on the top row; the second row, AISI 316; the third row, titanium; and on the bottom, Haynes 25. The amount of pressure used increases from left to right.

FIG. 5

Autoradiographs of the screw heads showing metallic transfer from the radioactive cobalt-chromium-molybdenum screwdrivers (Table VI). Cobalt-chromium-molybdenum screws are on the top row; the second row, AISI 316; the third row, titanium; and on the bottom, Haynes 25. The amount of pressure used increases from left to right.

counting position to standing upright on the x-ray film may be an explanation. Arranging the wooden blocks on the film inevitably involved some manipulation. The calculation of the actual transferred radiation should thus be given greater credit than the autoradiographs. When comparing different groups, it must be remembered that it is extremely difficult to reproduce the amount of torque and slippage from group to group. However, the important point is whether serious metallic transfer or flaking occurs on contact between a particular screwdriver and a particular screw. Every attempt was made to standardize the procedure. It will be noticed in comparing Tables VII and VIII with Tables II through VI that the amount of transfer detected is often less when plastic paint is used to trap flakes than when it was not used. The fact that flaking did not necessarily occur with each contact of the driver with the screw presumably explains this. However, transfer of metal always occurred. The difficulty in this experiment lies in distinguishing between flaking and metallic transfer. From the surgeon's point of view, however, both are best reduced to a minimum.

Thus, it has been shown that screwdrivers of five types all contaminate orthopaedic screws during their insertions. This contamination is due to both metallic transfer and metal flaking of the screwdriver. The amount of metallic transfer from the drivers showed no decrease with repeated use.

Although the quantitative nature of the results is difficult to assess accurately, the fact that serious metallic transfer and metal flaking occurs is important. By calculating amounts of metal transfer by the radiation counting technique we can draw certain tentative conclusions. The AISI 410 and 316 drivers

FIG. 6

Autoradiographs of the screw heads showing metallic transfer of radioactive screwdriver metal (Table VII). The areas of radioactivity adjacent to the screw heads come from flaked pieces of the drivers. The top two rows are AISI 316 screws, and the bottom two rows, cobalt-chromium-molybdenum screws.

Note that the AISI 420 driver gave transfers of eight and twenty micrograms to the two AISI 316 screws and two and three micrograms to the two Co-Cr-Mo screws.

were shown capable of contaminating all types of screws. This did not always occur with heavy pressure or it was not always detected. Transfer from an AISI 316 driver of eight micrograms of metal to an AISI 316 screw with slight slip and a similar amount to a titanium screw with medium slip are recorded in Table III.

The AISI 420 driver transferred only slightly to any screw except those made of cobalt-chromium-molybdenum to which transfer was once as high as ninety-one micrograms. It must be noted again that serious transfer does not always occur, although it is possible. However, of the drivers tested, the one made of AISI 420 seemed preferable. Its only rival was the hard, tool-steel driver which gave a minimal amount of transfer to all screws; with the heaviest pressure, thirty-eight micrograms was transferred to a cobalt-chromium-molybdenum screw. The tool-steel driver, however, is extremely hard and thus tends to cut the screw head. When this is severe, it might lead to corrosion of the screw due to locally altered metallurgical conditions. The cobalt-chromium-molybdenum driver (cast metal) transferred moderately to one or more screws of each group. Its hardness is similar to that of the cobalt-chromium-molybdenum screws; it is known that transfer is greatest between like metals. It seems reasonable to sug-

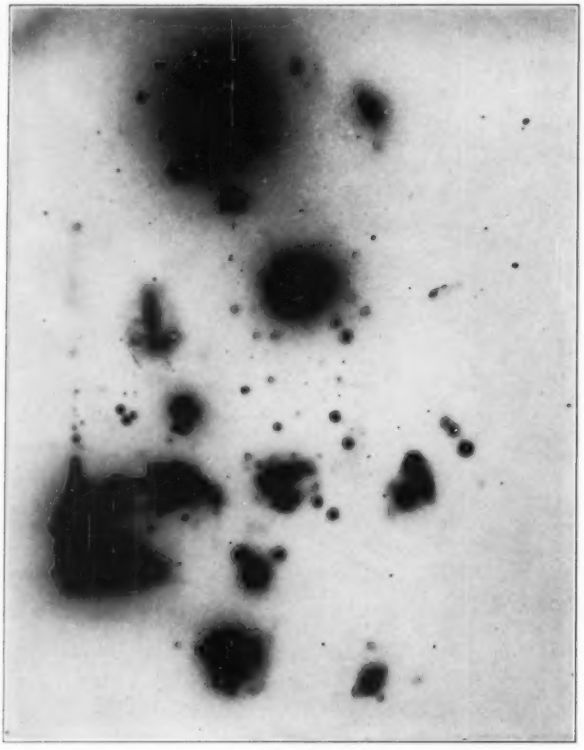


FIG. 7

Autoradiographs of the screw heads showing metallic transfer of the radioactive driver metals (Table VIII). Note the heavy contamination of the wooden blocks adjacent to the screw heads due to the flaked pieces of the driver. The top two rows are AISI 316 screws; the bottom two rows are cobalt-chromium-molybdenum screws.

Note that the AISI 420 driver gave transfers of twenty-six micrograms a AISI 316 screw and seven micrograms to a Co-Cr-Mo screw. These figures may be compared with the results from the same driver and screws in Table VII.

gest that a driver made of cobalt-chromium-nickel-tungsten alloy (wrought Vitallium) might be used with cobalt-chromium-molybdenum screws; however, such a driver was not available when this work was done.

The actual weight of metal contamination varied from one microgram to 330 micrograms. Some transfer always occurs although it may not always be large. Reducing this contamination, which is probably inherent in any unlubricated metal-to-metal contact, naturally suggests lubricating the screw slot. This is being investigated.

In the meantime it seems possible to make a tentative choice of a suitable metal for surgical screwdrivers. The results of animal experiments [10] and these current experiments allow us to make the tentative conclusion that an AISI 420 screwdriver would be suitable for AISI 316, titanium, and cobalt-chromium-nickel-tungsten screws. As far as cobalt-chromium-molybdenum screws are concerned, the decision is a little more difficult. Certainly, the cobalt-chromium-molybdenum driver contaminated, to a moderate extent, all screws of the same alloy. Perhaps a driver made of a similar but not identical alloy, for instance,

cobalt-chromium-nickel-tungsten, would be advisable. This metal should not prove so hard that excessive slot damage would be a factor in corrosion.

The importance of protecting implants from metal contact in storage and during sterilization and insertion is obvious. The careful use of screw-holding, non-slip screwdrivers must be re-emphasized, for then there will probably be less slippage and thus less foreign metal contamination.

SUMMARY

1. Radioisotopic techniques were used to assess the amount of contamination of orthopaedic screws by screwdrivers. Drivers made of five alloys were tested on screws made of four metals.

2. Two factors were found to be involved in this contamination: metallic transfer, and flaking of large pieces of the tip of the screwdriver by the cutting action of the screw slot against the driver.

3. Quantitative results show much variation and do not allow definite conclusions. However, we tentatively suggest that, of the screwdrivers tested, an AISI 420 stainless-steel screwdriver seems slightly preferable to others in handling AISI 316 and titanium screws; cobalt-chromium-nickel-tungsten drivers might prove useful in handling cobalt-chromium-molybdenum screws. Further research, especially with the goal of decreasing metallic transfer by lubrication, is needed.

NOTE: We are indebted to Dr. Albert B. Ferguson, Jr., in whose unit the work was done, for financial aid and encouragement, to Dr. Campbell Moses, Jr., who arranged for the irradiation of the screwdrivers, and to the following firms for gifts of materials and technical cooperation: Zimmer, DePuy, Richards, Medical Research Specialties, Austenal Laboratories, Crucible Steel, Universal Cyclops Steel, and Haynes Stellite.

REFERENCES

1. BOWDEN, F. P., and TABOR, DAVID: The Friction and Lubrication of Solids. London, Oxford University Press, 1950.
2. BOWDEN, F. P.; WILLIAMSON, J. B. P.; and LAING, P. G.: Metallic Transfer in Screwing and Its Significance in Bone Surgery. Nature, **173:** 520-522, 1954.
3. BOWDEN, F. P.; WILLIAMSON, J. B. P.; and LAING, P. G.: Letters to the Editors. Clinical and Metallurgical Observations on the Corrosion of Stainless Steel Screws Used in Orthopaedic Surgery. Nature, **173:** 1187, 1954.
4. BOWDEN, F. P.; WILLIAMSON, J. B. P.; and LAING, P. G.: Metallic Transfer in Screwing and Bolting and Its Significance in Bone Surgery. Report of Radioisotope Conference. Vol. I. London, Butterworth and Co., Ltd., 1954.
5. BOWDEN, F. P.; WILLIAMSON, J. B. P.; and LAING, P. G.: Significance of Metallic Transfer in Orthopaedic Surgery. Nature, **174:** 834-835, 1954.
6. BOWDEN, F. P.; WILLIAMSON, J. B. P.; and LAING, P. G.: The Significance of Metallic Transfer in Orthopaedic Surgery. J. Bone and Joint Surg., **37-B:** 676-690, Nov. 1955.
7. HARWOOD, J. J.: The Influence of Stress on Corrosion. Corrosion, **6:** 249-259 and 290-307, 1950.
8. KEY, J. A.: Electrolytic Absorption of Bone Due to the Use of Stainless Steels of Different Composition for Internal Fixation. Surg., Gynec., and Obstet., **82:** 319-322, 1946.
9. LAING, P. G.: The Influence of Metallic Foreign Bodies on the Inertness of Vitallium Screws. Canadian Services Med. J., **11:** 787-790, 1955.
10. LAING, P. G.: The Significance of Metallic Transfer in the Corrosion of Orthopaedic Screws. J. Bone and Joint Surg., **40-A:** 853-869, July 1958.
11. VENABLE, C. S., and STUCK, W. G.: Results of Recent Studies and Experiments Concerning Metals Used in the Internal Fixation of Fractures. J. Bone and Joint Surg., **30-A:** 247-250, Jan. 1948.

Unexpected Roads to Greatness*

BY H. RELTON MCCARROLL, M.D., ST. LOUIS, MISSOURI

The founders of The American Academy of Orthopaedic Surgeons in 1931 decreed that at each annual meeting there should be one presentation dignified by the title "Presidential Address." It would require a gross stretch of your imagination so to classify that which you are about to hear today but I ask your indulgence as we attempt to fulfill the requirements of the bylaws for this, the twenty-sixth annual meeting of our Academy. Upon realization two years ago that this would be my responsibility, a review of all available past presidential addresses was begun. Unfortunately, few of these addresses have been published but it has been my good fortunte to hear all with the exception of four. Each of these has been a masterpiece in its own right. Some have been strictly scientific in nature; some have been historical in type and have dealt with the growth and development of The Academy and of orthopaedic surgery; some have dealt with the pressing problems of the times; and still others have attempted to unfold the unlimited possibilities of the future. There seems to be little of value which I could add along these lines. After much deliberation and frequent change of plans, I have elected to consider with you this morning a thought which is suggested by a Biblical passage found in the forty-sixth verse of the first chapter of John. In this we find these words: "Nathanael said unto him, 'Can any good thing come out of Nazareth?' Philip said unto him, 'Come with me and let us see.' "

We can picture two men dressed in the robes of Biblical times standing on a slope outside the city of Jerusalem discussing the stories which had come across the Judean hills of the wonderful work of a man named Jesus. Nathanael being somewhat skeptical, as most of us would be, asked who this man was and where he came from. After learning he was born in Bethlehem and that his parents lived in Nazareth, his skepticism increased still further, for he had serious doubt that anything of great importance could come from such a small place. Jerusalem was the leading city of their time and represented the center of greatest accomplishment in all things of importance. Surely if anything of such great import was to take place in their time, one would expect it to originate in Jerusalem. It is significant that Philip made no attempt to answer the question but simply said, "Come with me and let us see." The answer to Nathanael's question has, in fact, been unfolded with the turning of each page of history during these past 2,000 years.

Comparing Nazareth to the city of Jerusalem in Biblical times would be similar today to comparing the sleepy little village of Evening Shade with the great city of New York. It would be like comparing the main street of Strawberry with the beautiful Michigan Boulevard skyline of the city of Chicago. To have such an important individual come out of the little hamlet of Nazareth would be comparable to having a rural Justice of the Peace or a small county Judge originate a workable plan for world peace, acceptable to all nations, when one ordinarily would expect such to originate in the United Nations which was founded for this very purpose. In medicine it would be comparable to a country doctor in a small community discovering a method for the cure and control of all cancer when one ordinarily would expect such an outstanding contribution in this field to come from the research laboratories of one of our great medical centers.

More than thirty years ago a scared country boy came out of the cotton fields of Arkansas and into a large city in quest of a medical education. On the

* Presidential Address read at the Annual Meeting of The American Academy of Orthopaedic Surgeons, Chicago, Illinois, January 26, 1959.

second day following registration, the freshman class met with the Dean of the school, as was the custom in those days. The Dean delivered the usual word of welcome but proceeded rapidly to warn that at the end of the first year 25 per cent of this class would be dropped and at the end of the second year one-third would no longer be among those present. This scared country boy, hoping to discover some reason for optimism, reviewed the class roster and the background of each individual member but this served only to intensify his growing apprehension. In this group were students with bachelor's and master's degrees from most of the leading universities of this country. The school from which he came (Ouachita College) was entirely unknown. If the name of the school appeared in print, no one could pronounce it and if it was pronounced no one could spell it. Realizing the competition and the fast company with which his lot had been cast, cotton picking, with each passing day, began to loom as a profession with ever increasing importance. On the following Sunday, when class assignments had not yet been made and study had not begun, this lad wandered to a corner church in the rooming house district in which he lived. The minister on that morning, Dr. John Porter, must have known that his audience would be dotted with country boys and girls who had arrived in the city for the first time to embark on an educational venture. He chose to speak that morning from the passage under consideration and proceeded to relate how many of the great men of this world and of our country had come from insignificant and unknown backgrounds and yet, through hard work and perseverence, had been able to carve a name for themselves. Encouraged by the only kind remarks which he had heard in a week and influenced partly by the fact that his tuition had been paid and was non-refundable, this same country boy decided to "stick around" for a while and find out for himself how the higher echelons of this world live and progress. It will not be necessary to bore you with the details of the struggle which followed, but it can be stated that at the end of four years, graduation day arrived and, thanks to the grace of God and the oversight of the faculty, this same little boy was permitted to creep to the podium of success and receive his M.D.

The road to greatness may arise in an unmarked trail. Few people would have dared hope when the Pilgrims landed at Plymouth Rock or when the *Declaration of Independence* was signed in Independence Hall that, in a short span of two or three centuries, this country would rise to its present position of world leadership. In the growth and development of this country, there are many examples of individual achievements by men who started, literally, with nothing. In the year 1763 a young man was born in the village of Walldorf near Heidelberg, Germany, and in his late adolescent years was employed in the piano and flute factory of his uncle. At the age of twenty he emigrated to America and it is stated that he had only twenty-five dollars with which he hoped to open a music store in New York. On voyage to America he became acquainted with a fur trader who advised him that a great future awaited some energetic young man in this field. Following this advice, the young man devoted many years to developing and organizing the fur trade in America and later by way of the Hawaiian Islands in China and India. The trials and incidents of this young man's undertaking were the theme of the great novel *Astoria* by Washington Irving. He died in New York City in 1848 leaving a fortune estimated at approximately thirty million dollars, at that time the greatest fortune amassed by any American. That man was John Jacob Astor.

The success story of Walter P. Chrysler is one of the greatest in modern business annals. Born in Kansas in the year 1875 of parents of meager circumstances, he first worked as a sweeper in the shops of the Union Pacific Railroad, then as an apprentice, and later as a machinist. Having no money with which to buy tools, he made his own. Today these tools are kept on permanent display in a glass enclosed case in the Chrysler Building. Through his own mechanical ingenuity and ability he advanced rapidly in his field and could undoubtedly have be-

come one of the leaders in the railroad industry. In 1908 he borrowed money to buy a $5,000.00 automobile (Locomobile) which he had seen at the Chicago automobile show, then took it apart and reassembled it eight times in the next three months before it was driven. The knowledge thus acquired served as the stimulus for his entrance into the automobile industry in 1911. Still later he entered business for himself and developed one of the leading automobile dynasties of our day. The great Chrysler Building in the city of New York stands today as a tribute to the ability and ingenuity of one man who began his life with nothing.

Perhaps the greatest success story in American history is that of the life of Abraham Lincoln. Born in 1809 in a log cabin on a farm in Hardin County, Kentucky, this young man was literally self-educated. It is estimated that his total schooling would have amounted to less than twelve months. As a youngster he worked on his father's farm and later worked as a grocery clerk in the little village of New Salem, Illinois, to which they had moved. He worked on a flatboat making two trips to New Orleans and this, as it turned out, had much to do with the patterning of his future life. He operated a store in partnership with a man named Berry but this failed, leaving debts which Lincoln assumed and paid off painfully during a period of fifteen years. Payment from the jobs which he held did not suffice for a livelihood so in desperation he borrowed a book on surveying, and after this study supported himself by working as a surveyor for several years. Through the friendship of a man named Stewart he was able to borrow books to study law, obtained a license to practice, and moved to Springfield, Illinois, in April 1837. He entered politics but experienced success on only a few occasions until his election to the Presidency of the United States in 1860. Even then he received less than half of the total votes cast. Abraham Lincoln, a man for whom two cities and a great highway have been named, a man to whose memory more monuments have undoubtedly been erected than to any other American, carved a place for himself in American and world history which will live forever, yet he came from the most insignificant background it is possible to imagine.

The moral implied in this story has been repeated many times over in every phase of human endeavor and many examples may also be found in the history of American medicine and orthopaedic surgery. The American Academy of Orthopaedic Surgeons, now only twenty-eight years old, was formed almost a half century after The American Orthopaedic Association. The American Orthopaedic Association at that time was already a great organization with a history of great accomplishments. There may have been some reasonable doubt in the minds of the founders of The Academy as to whether it could ever assume a position of importance equal to that of The American Orthopaedic Association. Yet in the short span of approximately one-quarter century, this Academy has grown into the world's largest orthopaedic group, holds one of the largest annual meetings devoted entirely to the orthopaedic field, and, in accordance with its name, has taken the leadership in the training and teaching of young men. Harold Boyd tells of standing with Willis Campbell at the rear of the auditorium of the Hotel Peabody during the 1939 meeting of The Academy, when Dr. Campbell remarked, "Harold, you will live to see the day when 500 doctors will attend the meetings of this Academy." It would be interesting to know his reaction today if he could attend one of our present meetings with a total registration of over 4,000. With a membership of over 2,500, The Academy has reached the position of co-owner and joint publisher of *The Journal of Bone and Joint Surgery* and its various committees are actively engaged in the study and advancement of all ramifications of orthopaedics.

The lives of many orthopaedic surgeons also serve as a positive answer to the question, "Can any good thing come out of Nazareth?" Many young men today, still in training in orthopaedic surgery and struggling for their start, undoubtedly find it easy to conclude that the great men of our specialty in years gone by must have had it much easier when they began. Such, however, is not the

case. Most of the greatest contributors to our specialty were faced with adversities and lack of financial help during the early portions of their careers. It has always been true and is still true today that young orthopaedic surgeons often begin in an unpretentious way, with little or no financial help, but still develop in the specialty of Orthopaedics to a position of world renown. For example, a young man was born in Boston, Massachusetts, in 1868; his father left shortly afterward to serve with the Union Army and remained in the Army for many years. This young man, lacking financial assistance, arranged for his own medical education at Harvard University and took his internship in the McLean Hospital. In spite of this financial difficulty and lack of help and encouragement, he continued to work diligently and endured many hardships in the devotion of his life to orthopaedic surgery. Even the family of the girl he married felt she was throwing herself away on a penniless young doctor. Few men, however, have made greater contributions to our specialty than this man, Royal Whitman, who played such an important role in the development of the Hospital for the Ruptured and Crippled.

Another great orthopaedic surgeon was born in Jackson, Mississippi, in the year 1890, and was graduated from Johns Hopkins Medical School in 1918. He was a member of the famous class which spent their senior year in France as members of the Armed Forces Medical Corps and actually received his M.D. while on duty in Europe. It had been necessary for him to drop out of medical school for one year because of lack of finances and during this year he served as an Instructor of Anatomy at Creighton University. After his army service, he obtained his training in orthopaedic surgery in Boston. During one of these years he served as an Instructor in Applied Physiology at Harvard Medical School. During the next two years he lived in Baltimore and then moved to St. Louis as head of the new research unit of the Shriners' Hospitals for Crippled Children. In 1931 the research unit of the Shriners' Hospital closed and this young orthopaedist suddenly found himself without income. He entered practice and succeeded Leroy Abbott as Professor of Orthopaedic Surgery at Washington University, serving in this capacity until his death in 1956. This man, J. Albert Key, one of the greatest contributors of all time in the field of orthopaedic surgery, had no financial help during his training period and for many years after entering practice had a very limited income.

The father of an infant boy, one year old, died in Grimstad, Norway, in 1887. The young mother, a talented musician and violinist, had three other sons, all under eight years of age. There was little money for the support of her boys so she moved to Oslo where the opportunities for her teaching and for the education of her boys seemed more promising. It took much self-sacrifice and frugal living to keep her family together. As the boys grew, the youngest became a close friend and almost constant companion of the son of Dr. Jon Hald. Out of this friendship and inspiration there grew a determination in the mind of the young boy to study medicine, although his family background was filled with musicians, shippers, bishops, lawyers, and business men. Two of the older sons emigrated to America, so this young boy and his mother followed in 1903 and moved to Milwaukee where the oldest son lived. They were penniless when they reached Milwaukee, but the boy, now sixteen years old, was thrilled to find a medical school right there where he could be "taken in" despite his inadequate preparation. It took only a few days for him to realize this was a racket which issued medical degrees for a price. He then completed high school and attended Rush Medical College for one year in the days before college training was required. Realizing he was not prepared for medicine, he returned to the University of Wisconsin where he graduated, a member of Phi Beta Kappa, at the end of three years. During this time he paid his own way by doing small jobs and by working every summer as paymaster for a railroad. He then completed the two-year medical course which was offered in Wisconsin at the time. Following the

advice of Dr. John Yates of Milwaukee for whom he had worked during vacation periods, he then transferred to Harvard University where he received his M.D. This was made possible by a loan of $5,000 from a friend of Dr. Yates. This seemed a fortune to the young man and it took careful spending and planning to complete his training. It is stated that on one occasion his food for a week consisted of milk and a box of shredded wheat eaten in his small attic room. This same boy, Marius N. Smith-Petersen, became Professor of Orthopaedic Surgery at Harvard University, made many outstanding contributions to our specialty which have stood the test of time, and served as the Twelfth President of The Academy.

One of the greatest success stories involving two orthopaedists had its beginning with the birth of a boy in Vienna, Austria, in 1878. This young man received his M.D. from the University of Vienna in 1902 and came to the United States in 1907. The intervening five years he spent in hospital training and service. After reaching the United States, he elected to come to the "Western Frontier of Orthopaedic Surgery" and spent the next three years in Chicago as an assistant to Dr. John Ridlon. In 1910 he became Professor of Orthopaedic Surgery at Drake University Medical School in Des Moines. Much of his work was done at the Methodist Hospital where a new x-ray machine had been obtained but where no facilities existed for its use. No dark room was available and the only facilities in the city of Des Moines for developing the glass plates existed in a corner drug store, some seven or eight blocks away. This young orthopaedist took his own x-rays, walked down the hill to the drug store to have them developed, then returned to the hospital to institute the treatment indicated. How many of us would be willing to work under such adverse conditions today? A young lad, the nephew of the owner of the drug store, worked in this drug store during the summer months. He was greatly impressed with the thoroughness and the ability of the young orthopaedic surgeon, became interested in his x-ray plates, and learned to develop them for him while he waited. The surgeon soon began to explain the shadows on the plates to the young man and he in turn began to understand how this new doctor seemed to obtain better results. The Medical College of Drake University closed in 1913 at which time the surgeon moved to Iowa City as an instructor at the University of Iowa School of Medicine. In 1915 he was appointed full Professor of Orthopaedic Surgery, a position which he held for thirty-four years. This man, Arthur Steindler, also became one of the greatest contributors orthopaedic surgery has ever known. He carried on his teaching and his research program without any outside grants. Dr. Steindler has stated: "If you are determined enough, a great deal of research work can be done without outside grant or help provided you are willing to spend the time for it and again provided that the research does not require any expensive or elaborate equipment." The young man working in his uncle's drug store in the summer of 1913 received an inspiration from Dr. Steindler which carved his life's work. Because of the stimulus derived at that time, he studied medicine, entered the field of orthopaedic surgery, and became the Sixteenth President of The American Academy of Orthopaedic Surgeons. That man was Myron Henry.

Examples of this type in which many great men of our specialty have made their start without financial help and who have carried on their work against adverse circumstances should serve as an inspiration for any younger man entering orthopaedics today. With the passing of each generation of great men, it is, in the same manner, only natural to feel that perhaps the greatest men of all time in this specialty have passed from the scene. We should always remember, however, that Hippocrates never heard of Ambroise Paré; Paré never heard of Nicholas André; André never heard of Sir Robert Jones; and Robert Jones never knew of the full accomplishments of Marius Smith-Petersen or J. Albert Key. Unfortunately, Smith-Petersen and Key were not privileged to know of the contributions which the younger men of this generation will make. While a great

man is being honored in any field some younger individual, then obscure and unknown, may already have instituted work which will serve as a greater contribution. Let us not forget that there are always younger men coming up the ladder who will ably take the places of the leaders of years past and whose contributions may stand as the greatest of all time. Many young orthopaedic surgeons have survived their years of medical education and graduate training with no financial assistance, and many more are enduring such hardships at this time. Unfortunately this is often a deciding factor when the young surgeon comes to select the type of practice or the permanent location for his future career. While it is essential that he have sufficient income to support his family and educate his children, it should be remembered that happiness in scientific work is not dependent upon financial gain. Immediate financial success is not essential and at times not even desirable. Early financial success may, in fact, be detrimental to stimulus for truly scientific achievement. Any young orthopaedic surgeon today should be encouraged by the fact that most of the great contributors and most beloved men in our specialty have endured the same hardships and adversities with which they are now confronted.

In today's class of 150 entering the ranks of The American Academy of Orthopaedic Surgeons, there are many young men whose contributions to the field of orthopaedics will be outstanding. If we could look into the future some fifteen or twenty years and identify those whose contributions will be lasting and beneficial, you today would receive a special welcome. Some of the members of this class, within a period of fifteen or twenty years, will serve as the leaders of this Academy, and some of you will even find it necessary to worry about a "Presidential Address." Again if we could look into the future and know those of you who will serve as the leaders in the years to come, great honor would be bestowed upon you even at this early stage of your career. Fortunately, however, your future contributions and accomplishments are unknown and, theoretically, at least, each of you starts with equal opportunity. As one grows older in orthopaedic surgery and advances up the ladder of authority in this Academy, it is not uncommon to have the question asked by a young orthopaedist, "What should I do and what course should I follow to some day have the privilege of being of service to The Academy and orthopaedic surgery?" While I make no attempt to pose as an authority in this field, the answer to this question is really not a difficult one, and can be grouped under two major headings:

Scientific Accomplishment and Contributions

It is essential that you make some scientific contributions to the medical literature and to the programs of our national meetings. Those of you who live in smaller communities may feel that no opportunities exist for such accomplishments by you. It should be remembered, however, that columns of brick and stone and the marble halls of great universities do not necessarily insure originality of thought. Any individual, regardless of the size of the community in which he lives, may conduct clinical research which will afford adequate material for a scientific paper. With the completion of such work, its presentation before a national medical meeting, and publication in *The Journal of Bone and Joint Surgery*, your name will be established as a contributor in the field.

As a background for scientific accomplishment and contributions, the following prerequisites cannot be overemphasized:

1. Adequate and acceptable training in orthopaedic surgery (This is self-explanatory and serves as the keystone on which all progress is based. Even though Abraham Lincoln rose to great heights with less than twelve months of formal education, we are not justified in abolishing our present educational system or altering our training programs in the hope that by so doing an entire nation of Lincoln giants will be created in the field of orthopaedics.);

2. Clear thinking; clear thinking is an attribute with which many are born

but this may also be developed during the training period;

3. Accurate knowledge of the works of other men in the field; knowledge of the works of others is derived from continuous study of past and current literature. It is essential for proper evaluation of your own problems and findings;

4. Hard work; assuming that each individual is endowed with or has acquired the previous qualities, the next step on the road to recognition results from incessant toil or hard work. Thomas A. Edison once stated, "Genius consists of 10 per cent inspiration and 90 per cent perspiration." This is as true in medicine as it is in any other field. It is essential that you literally love your work and devote your maximum time and ability to orthopaedics. You can hardly expect to attain great success if your primary interest in life is devoted to fishing or golf and orthopaedics serves you only as a means for livelihood.

Honesty and the Willingness to Take Your Position on the Side of What You Consider Right

Honesty in your own scientific work, in the evaluation of results, and in the conclusions reached is essential if you expect your contributions to stand the test of time. Your ideas in any given problem must be founded on sound basic principles of the pathology involved. When these requisites are fulfilled you should then be willing to take your position on the side that you consider right even though your findings, your results, and your opinions may be contrary to those commonly accepted at the time.

Once an individual has established himself in orthopaedics through scientific achievement and contributions, he will soon be requested to serve in some Academy position of importance. This, as a rule, is in the form of membership on one of the Academy Committees. When you have reached this stage in your career and are asked to serve in any capacity on a committee, you should do so to the best of your ability. Be original in your thoughts and your ideas, devote much time and effort to the work of the committee, and, in this way, help to advance the cause of orthopaedic surgery. Once this initial assignment has been completed with distinction, your future development represents a matter of advancement with time, age, and maturity. You may be asked to serve as a junior member of the Executive Committee, as an examiner for the American Board of Orthopaedic Surgery, or as a member of the Board of Associate Editors of *The Journal of Bone and Joint Surgery*. The next step may be the Chairmanship of a Committee. Not every individual, of course, can rise to the status of officer in an organization comparable to The Academy and we must admit that luck plays an important role in this final achievement. Each man of this class today, however, if the suggested plan is followed, will be privileged to serve orthopaedics in some capacity, either through this Academy or some other division of our specialty.

"Can any good thing come out of Nazareth?" Yes, so long as young men and young women are willing to start at the bottom and work their ways to the top, so long as they are willing to endure the hardships which this necessitates, so long as they maintain an interest in the humanities and continue to enter the fields of music, art, religion, education, and science, and so long as they continue to devote their lives to the various fields of medicine and surgery, not the least of which is orthopaedics, this thought will continue to form the theme of a story which will never grow old.

Proceedings

WESTERN ORTHOPEDIC ASSOCIATION

As Prepared by the Editorial Committee: Kirk J. Anderson, M.D., *Chairman;* Ivar J. Larsen, M.D., Robert Mazet, Jr., M.D., John R. Schwartzmann, M.D., and Howard A. Mendelsohn, M.D.

The Twenty-second Annual Meeting of the Western Orthopedic Association was held in Portland, Oregon, October 22 through 25, 1958, under the Presidency of Dr. Joe B. Davis. The meeting was well attended with representation of members and guests from the sixteen chapters of the Western Orthopedic Association. The program included papers of both clinical and research interest. In addition, an excellent panel discussion was provided on the legal aspects of orthopaedic surgery.

As in the past, emphasis was directed to the Resident-Training Program under the chairmanship of Dr. Howard A. Mendelsohn. The Resident-Training Program awards named in honor of the originator, Dr. Vernon P. Thompson, were given to the following essayists: First Prize (tied), $300.00: to L. C. Folkes, M.D., for "The Relative Importance of Periosteum and Blood Supply in Fracture-Healing," and an equal amount to Albert F. Martin, M.D., for "The Pathomechanics of the Knee Joint." Second Prize, $200.00: W. D. Guyer, M.D., and C. A. Fagan, M.D., for "Cavus Deformity of the Foot." Third Prize, $100.00: William Burkhalter, M.D., "Prosthesis Arthroplasty of the Hip," and an equal amount to Howard R. Baker, M.D., for "Non-union of Fractures of the Trochanteric Area of the Femur."

At the close of the session bronze medallions, depicting the first historically recorded orthopaedic procedure in the West, were presented to the Past Presidents. The medallions were presented by Dr. Harold Crowe who outlined the advancement made by each President of the Association, as well as points of interest regarding each one of these men. A special tribute was paid to Dr. Charles L. Lowman who is now in his fifty-second year of the practice of medicine. Dr. Crowe remarked: "Dr. Lowman is still practicing at full capacity and not only talks posture with great enthusiasm but maintains posture himself without the usual stooped shoulders and paunch which ordinarily go with the passing of the years." It was only fitting and proper that Dr. Crowe officiate in this capacity inasmuch as his interest in the Association has been a constant stimulus to its members.

Dr. William F. Stanek of Denver, Colorado, was installed as President for the coming year. The next Annual Meeting will be held in Denver, Colorado, October 18 through 22, 1959. Officers elected for 1959 were:

President-Elect: Fraser L. Macpherson, M.D., San Diego, California;
Vice President: J. Sims Norman, M.D., Pueblo, Colorado;
Secretary: Alba R. Glassburn, Jr., M.D., Denver, Colorado;
Treasurer-Historian (for three years): Walter Scott, M.D., Los Angeles, California;
Editorial Committee (new member): Donald E. Moore, M.D., Eugene, Oregon.

The 1960 meeting will be held in San Diego, California, under the Presidency of Dr. Fraser Macpherson.

Summaries of the papers presented follow:

The Effect of Antihistamine on Experimental Fat Embolism in Rabbits. Dr. R. C. Merrifield[1] reported a research project concerned with the premise that histamine liberation from tissue injury is a potent, harmful factor in fat embolism. The protective effect of antihistamine in experimental fat embolism in rabbits was investigated. The pathogenesis of fat embolism was described as a rupture of the fat cell by trauma or necrosis. The liberated fat is forced by pressure of a hematoma into the general circulation through torn veins to produce embolic phenomenon or bronchoconstriction, capillary damage, and alveolar oedema in the lung. The fat then may find its way into other organs, particularly the brain. The cause of the fat-cell rupture may be secondary to fracture, soft-tissue trauma, enzyme action, as in pancreatitis, or external body-pressure changes as in diving or high-altitude flying.

Fifty rabbits received intravenous injections of olive oil to produce fat embolism. It was noted that the olive oil, proportional to the weight of the rabbit, produced a wide variation in mortality rate in different weight groups. The average mortality rate in this group of animals was 68 per cent. A second group of fifty rabbits received intramuscular injections of five milligrams per kilogram of body weight of antihistamine thirty minutes before the intravenous injection of oil.

1. Veterans Administration Hospital, Department of Orthopaedic Surgery, Portland 7, Oregon.

The results were: The antihistamine given before an oil dose of 0.7 cubic centimeter per kilogram of body weight reduced the mortality rate from 50 per cent to 30 per cent in rabbits weighing 1.8 kilograms, 50 per cent to 40 per cent in rabbits weighing 2.05 kilograms, and from 80 per cent to 40 per cent in rabbits weighing 2.3 kilograms. The antihistamine given before an oil dose of 0.8 cubic centimeter per kilogram of body weight reduced the mortality rate from 70 per cent to 60 per cent in rabbits weighing 1.8 kilograms and from 90 per cent to 60 per cent in rabbits weighing 2.05 kilograms. The antihistamine reduced the average mortality rate of all rabbits from 68 per cent to 46 per cent. Convulsions were noted in 13 per cent of the rabbits that received injections of oil only. Antihistamine administration before injection of olive oil reduced the convulsion rate to 2 per cent.

The author concluded that antihistamine has a protective effect in mortality from fat embolism and reduces the convulsion rate in rabbits with fat embolism.

Dr. Lawrence Cohen [2], in his discussion, stated that olive oil is a relatively non-toxic substance and its action is essentially mechanical. In comparison, bone-marrow fat, which is composed largely of olein, is more toxic. He felt that the experiment should be repeated using oleic acid and the same dosage of antihistamine for comparison.

Orthopaedic Diseases in Small Animals. Dr. Francis T. Candlin [3] and Dr. James S. Miles [4] discussed a number of orthopaedic diseases that occur spontaneously in small animals and are not experimentally produced. These diseases, however, are etiologically similar to human disease and include disturbances of prenatal influence, metabolism, and growth, degenerative processes, infections, trauma, neurological and circulatory disturbances, neoplasms, and undiagnosed diseases. These diseases occur with considerable frequency in certain breeds or strains of small animals. Emphasis was placed on non-traumatic conditions, but some fractures and dislocations were included in the series to demonstrate the similarity presented by these problems to those in human beings.

Included in the discussion was osteogenesis imperfecta, very frequently noted in the Siamese cat and Capuchin monkey. Dysplasia and congenital dislocation of the hip were described in two dogs, the adolescent boxer and the English bulldog. Achondroplasia was noted in the basset hound. An example of rickets was demonstrated in the great Dane and diseases of growth, in the form of Legg-Perthes' disease, were noted in the West Highland white terrier. Osteochondritis dissecans was noted in the Labrador and Osgood-Schlatter's disease was described in the collie. Degenerative arthritis, particularly of the joints of the extremity, was described in several breeds of dogs. Of considerable interest was the finding of protruded intervertebral disc, as well as degenerative-disc disease at all levels of the spine, reported to occur most frequently in the dachshund and cocker spaniel.

Dr. Frederic Ilfeld [5], in his discussion, stated that this study should inspire more intensive research of orthopaedic disease in small animals.

The Mechanics of Football Injuries. Dr. Donald B. Slocum [6] stated that, while the end results of football injuries are well understood, an exact, early diagnosis often cannot be made and adequate treatment instituted without knowledge of the mechanics of the injury as an aid in understanding the pathological process. The author presented studies of the various conditions under which football injuries commonly occur. These studies were made from films of players injured during actual football games. An explanation of each frequent condition caused by trauma was presented.

Familial Occurrence of Small Subcutaneous Bony Deposits. Dr. Stanley S. Tanz [7] reported diffuse, small, subcutaneous areas of ossification, associated with evidence of endocrine disturbance and congenital anomalies, occurring in the extremities of three members of one family. The author believed that ossification in these individuals was secondary to metabolic bone disease, hyperparathyroidism, pseudohyperparathyroidism, or pseudopseudohypoparathyroidism. The author also presented a discussion of other disease processes such as myositis ossificans progressiva and calcinosis.

Radiation-Induced Osteogenic Sarcoma in Dogs. Dr. Terence H. Cochran [8], Webster S. S. Jee [9], and Dr. James S. Arnold [10] described a research project and experiment in which

2. 310 Selling Building, Portland, Oregon.
3. Consultant in Veterinarian Medicine, Halstead Laboratory for Experimental Study, University of Colorado Medical Center, Denver, Colorado.
4. Division of Orthopaedic Surgery, University of Colorado Medical Center, Denver, Colorado.
5. 436 North Roxbury Drive, Beverly Hills, California.
6. 750 East 11th Avenue, Eugene, Oregon.
7. 1548 North Norton Avenue, Tucson, Arizona.
8. Department of Pathology, University of Utah, Veterans Administration Hospitals, Salt Lake City, Utah.
9. Radiobiology Laboratory, University of Utah, Salt Lake City, Utah.
10. United States Naval Radiological Defense Laboratory, San Francisco, California.

osteogenic sarcoma was produced in an inbred colony of beagles following a single intravenous injection of various bone-seeking isotopes; namely, plutonium-239, radium-226, mesothorium (Ra^{226}), radiothorium (Th^{228}), and strontium-90. All animals received injections at an age comparable with young adult humans. They felt that the comparison of the findings in this colony of beagles with patients with radium poisoning would enable one to establish a more accurate maximum permissable dosage of these various isotopes in human beings. A study of the long-term effects of accurately determined dose levels of radiation on large mammals would also be possible.

The authors found that these isotopes, when in bone, showed a uniform distribution that fell into two patterns. Radium and strontium were primarily deposited in areas of bone formation, with some diffuse distribution, at the time of the single injection; this was probably related to an ion exchange with calcium. The other isotopes, those of plutonium, thorium, and mesothorium, localize on endosteal-bone surfaces with subsequent concentration in osteoclasts and reticulo-endothelial cells.

The variety of histopathological changes in bone is seen with all the isotopes but the retained dose level of each isotope determines what pattern of changes will be noted. These changes can be categorized as follows: (1) response to alpha-emitters by endosteal and bone-marrow cells, (2) disturbances in normal bone growth, and (3) disturbance in normal-bone renewal or reconstruction. Survey of at least one-half of the skeleton of each dog sacrificed revealed occult osteogenic sarcomata, frequently multiple and atypical cellular lesions. The authors found that osteogenic sarcoma occurred with the use of all the mentioned isotopes; over 50 per cent of these were not demonstrated clinically but were found at autopsy.

Small Element Lesions of the Cervical Spine Due to Trauma. Dr. Richard F. Wagner[11] and Dr. Martin S. Abel[12] reported that the best visualization of the cervical spine is obtained by making 30-degree caudad angled and 15-degree cephalad angled anteroposterior roentgenograms, in addition to coned-down occipital submental views. These films are best made in stereo with 0/3 millimeter tube and a short distance between tube and object for differential magnification. Standard views of the cervical spine are also made.

These techniques more readily disclose fractures of the lower interarticular isthmus, laminae, Luschka joints, and unilateral fractures of the first cervical vertebra, respectively.

One hundred patients with these lesions were analyzed. It was noted that orbital symptoms were seen only in patients with lesions of the upper part of the cervical spine and arm pain was associated with fractures of the lower part of the cervical spine; point tenderness was the most reliable sign of fracture at the designated site. Twelve patients were followed from two to three years, and all had residual symptoms localized at the site of injury.

The authors outlined the treatment program for small lesions of the elements of the cervical spine. The authors advised early use of a cervical brace, followed by traction. They feel that early use of traction is contra-indicated since it interferes with the healing of torn soft tissue and is detrimental to early callus formation. Eight weeks was felt to be the minimum time necessary to roentgenographically distinguish osseous union of a fracture of a small element; in the presence of such an injury the brace should not be discarded before this period.

The authors' experimental study included correlating the views of the lower part of the cervical spine seen in 2,000 roentgenograms of the chest. This study, of course, was incomplete because it ignored the lesions of the cervical spine at higher levels. Two findings were noteworthy: the frequency of lateral-mass deformities was quite high; and this incidence increased with age. The authors concluded that these deformities were acquired, not congenital. In addition, thirty-one non-selected cadavera were dissected; fractures were evident in more than 25 per cent. These fractures were diagnosed by the correlation of specimen roentgenograms, gross and microscopic anatomy, and microradiography based on the differential radiodensity of new and old bone. The findings indicated that lack of trauma and symptoms were not valid criteria for determining whether the cervical spine was normal. A study of arthritic changes in the cervical spines of these cadavera indicated that apophyseal changes were focused around old fractures or malalignments, independent of spurring or hypertrophic change about the cervical vertebral bodies. There was evidence that fractures of the small elements could act as foci for the development of rather extensive arthritis which might be symptomatic and appear to be a response to altered dynamic stress and strain as well as altered mechanics in the movements of the neck.

The Cervical Instability Syndrome. Dr. Norman M. Harris[13] and Dr. Anthony Smith[14] included in their report on cervical instability syndrome various symptom complexes arising from abnormal motion of the cervical spine. By using the cervical discogram and by noting the change in the patient's symptoms after cervical interbody fusion, the authors placed in

11. 450 Sutter Street, San Francisco 8, California.
12. 655 Sutter Street, San Francisco 8, California.
13. 517 Hall Building, Coos Bay, Oregon.
14. 517 Hall Building, Coos Bay, Oregon.

this syndrome a number of symptom complexes commonly considered to have separate origins. The pattern of pain produced by injecting an abnormal intervertebral disc at the time of the cervical discogram has also been utilized as the basis for categorizing various symptom patterns. The symptom patterns noted have been presented in the form of neck pain, headache, sclerotome type of pain in the interscapular area, chest, shoulders, and arms, vision changes, paraesthesia of the hands and arms, and specific symptoms of generalized weakness and asthenia. Although abnormal motions of the cervical spine are believed to be the common underlying cause, the authors feel that there are other mechanisms responsible for the symptoms: compression of the sensory roots accompanied by dermatome pain, hypaesthesia, and reflex change. Another cause might be motor involvement accompanied by sclerotome pain, muscle spasm, tenderness, weakness, and atrophy. Compression of the spinal cord or the anterior spinal artery, posterior sympathetic nervous-system involvement with production of the Barre-Lieou syndrome, or compression of the vertebral artery and anterior sympathetic system may also be related mechanisms. The authors believe that a better understanding of these symptoms will enable one to recognize the cervical instability syndrome and permit more rational and effective treatment.

In his discussion, Dr. Ernest M. Burgess[15] felt that the authors' etiological concept regarding the neck-shoulder-arm symptom complex was not necessarily wrong, but unproved.

Rear-End Collision Neck Sprains. Dr. Irving Tuell[16] stated that in recent years many patients have been treated for neck injuries received while sitting in a stationary automobile when struck from the rear by a second car. These have erroneously been called whiplash injuries, ignoring Newton's first law of motion. This condition has assumed a medicolegal significance disproportionate to its pathological and medical importance.

The term *whiplash injury* is traced to Arthur G. Davis who, in referring to the flexion type of injury, applied the term to the severely injured patient who was tossed about in a head-on collision. To clarify the mechanism of the injury in the typical busy-street, rear-end collision, the author showed motion pictures of such an injury sustained while riding in a car at speeds of ten and twenty miles per hour at the time of impact, with himself as the experimental subject. The results were filmed with ultra high-speed motion-picture film, and demonstrated that the head and the neck of the driver move according to Newton's first law of motion. The mechanism is purely one of inertia, causing hyperextension and traction of the neck without any flexion component.

Dr. Charles Bechtol[17] complimented Dr. Tuell for carrying out dangerous and necessary tests for his report. He agreed that the term *whiplash* creates an unfortunate semantic muddle and stated that engineering analysis has shown that in a collision at twenty-three miles per hour at the moment of greatest neck extension there is a backward force of eighty-four pounds and a downward force, extending the neck, of 308 pounds. Protection can be afforded by a headrest wherein the head and torso are accelerated at the same rate and no neck injury can follow.

A panel discussion, **The Legal Aspects of Orthopaedic Surgery,** was presented with Dr. Orville N. Jones[18] as *Moderator;* the other members of the panel were Judge Eugene K. Oppenheimer, B. A., LL.B.[19]; Hugh L. Biggs, B. A., LL.B.[20]; and Dr. George B. Long[21].

Dr. Orville N. Jones stated that the panel discussion was the result of the widespread interest expressed by the members of the Western Orthopaedic Association. He felt that the topic chosen was vital to every orthopaedic surgeon and was worthy of comprehensive discussion.

Judge Oppenheimer opened the discussion by directing his remarks toward the orthopaedic surgeon as an expert witness. He felt that the term *medical witness* should be viewed from two aspects: (1) the moral aspect, and (2) the manner of preparation of testimony and its presentation. Judge Oppenheimer said that the medical profession is a great science and stands high in respectability. People want to look to it with confidence and for guidance. Therefore, there cannot be a betrayal of faith and ideals because of monetary attraction. If the witness was the attending physician, then he should appear willingly and given his honest, expert opinion. If the medical witness was an examiner for the defense, he must testify as to his findings, favorable or unfavorable. Frequently, casual preparation precedes the actual presentation of facts by the medical witness. No one can instill the power of expression in a witness if he does not have that ability. However, conference and discussion can improve the manner of presentation. The manner of speaking and the posture in the witness chair can

15. 1110 Harvard Avenue, Seattle 22, Washington.
16. 1305 Seneca Avenue, Seattle 1, Washington.
17. University of California at Los Angeles Medical School, Division of Orthopaedics, Department of Surgery, Los Angeles, California.
18. 2311 N.W. Northrup Street, Portland 10, Oregon.
19. Multnomah County Circuit Court, Portland, Oregon.
20. Legal Counsel, Oregon State Medical Society, Portland, Oregon.
21. 812 S.W. Washington Street, Portland, Oregon.

be effective but the doctor should not assume the role of an advocate and should not take the offensive. This is the position for the lawyer.

Mr. Biggs discussed some of the legal aspects of malpractice as it particularly pertains to the orthopaedic surgeon. With the rise in incidence of malpractice litigation, the legal and medical professions have found a common ground. Through cooperation and the union of the two professions, a hybrid called Medical-Legal Jurisprudence has been born. He stated that in a random sampling of 5 per cent of the total membership of the American Medical Association, one of every seven members have had claims or action presented against him. The highest occurrence is in California where one of every four doctors is involved; the lowest incidence, one of every thirty-three, is in South Carolina. Thirty-one per cent of all malpractice claims have arisen in a specialized field, surgery; 20 per cent in the field of orthopaedic surgery, 20 per cent in medicine, 12 per cent in obstetrics and gynecology, and 17 per cent in the remaining fields. An interesting paradox exists: in the past twenty years there have been tremendous accomplishments made in the field of medicine but, nevertheless, the practitioner has never been so beset by claims submitted by disgruntled patients. Mr. Biggs stated that he did not wish to conjecture on the cause of this but stated that in view of these statistics one thing was clear; the doctor must think more about the problem of malpractice litigation.

Most malpractice litigations arise from (1) negligence; (2) statutory violations pertaining to the practice of medicine; (3) assault and battery based upon unauthorized operations and treatments; and (4) occasional libel and slander suits.

In defining negligence, Mr. Biggs stated that a doctor is not a guarantor of a cure and a bad result in itself does not make the doctor liable. However, a doctor may make himself liable by guaranteeing a cure; the books are not without cases in which doctors have done just that. The doctor is not liable for an error in judgment. This presupposes that the doctor is capable, on the basis of proper training, of forming an acceptable judgment on the medical or surgical problem at hand. The doctrine of *res ipsa loquitor* was discussed at length as it related to negligence and as the latter pertained to malpractice. Malpractice was then defined as failure to use the degree of care and skill which the average, competent doctor of the same class would use under the same or similar circumstances. It is the doing of an act which the average, competent doctor of the same class would not have done. Therefore, as it pertains to the orthopaedic surgeon, he must be judged according to and in relation to the average specialist's standard of care in his given community.

Dr. Long was introduced by Dr. Jones as being interested in the subject of malpractice and an authority concerning the medical phases of malpractice. Dr. Long stated that malpractice is a disease of the social body that is endemic and, at times, epidemic and that prophylaxis is the best means of handling it. Although he felt that his remarks might appear to be basic and elementary, he presented the following helpful advice. The physician should:

1. Show interest in the patient by utilizing tact;
2. Be available on the telephone;
3. Avoid resentment about fees;
4. Avoid being cold, abrupt, or insulting;
5. Keep complete records;
6. Have roentgenograms made before and after the treatment of fractures, obtaining as many as necessary;
7. Avoid criticizing another doctor's work (a lifted eyebrow can be as damaging as a spoken word);
8. Avoid doing what he is not qualified to do as a physician;
9. Ask for consultation when necessary;
10. Avoid self-condemnation;
11. Always obtain consent for surgical procedures, being sure that the permit is broad enough to cover all procedures that are anticipated. This should cover all those who will be engaged in the care of the patient; this particularly applies where an associate may be the operating surgeon;
12. Listen to the patient, and if the patient or relative is concerned about a particular diagnosis, accept the responsibility of being sure that it is either present or ruled out, and feel free to obtain consultation for paranoic patients;
13. Make an adequate examination;
14. Make use of available diagnostic and acceptable therapeutic procedures. If tests are denied, be sure the denial is recorded; and
15. Be sure to operate on the side of the lesion.

Straight Lateral Approach to the Hip with Preservation of the Abductors for Cup Arthroplasty or Prosthesis. Dr. J. Howard Varney [22] presented a report on the straight lateral approach to the hip, preserving the abductors. He has used this procedure in four patients who required prosthesis and eight needing cup arthroplasty on the hip. Only the skin, fascia lata,

22. 1801 28th Street, Bakersfield, California.

and anterior capsule of the hip joint are incised longitudinally. He believed preservation of the abductor mechanism results in a strong, stable hip and that hospitalization is shortened, usually to six days, when the abductors are not removed from the greater trochanter. He believed that severing the glutaeus medius and glutaeus minimus from the greater trochanter, then resuturing and starting motion prior to six to eight weeks results in separation in a large number of patients. This occurs in Achilles-tendon lengthening without a cast to prohibit movement. The operation is done with the patient lying on the healthy side. A padded Mayo table beneath the affected leg relaxes the abductors. A straight lateral incision is made in line with the femur, starting three to four inches above the trochanter and extending about six inches below. The fascia lata is exposed and slit in line with its fibers and followed upward to locate the tenor fascia femoris muscle. The glutaeus medius and glutaeus minimus are separated from the capsule by the fingers and retracted posteriorly so that the joint capsule may be entered. The head of the femur is then dislocated anteriorly and either replacement or cup arthroplasty is done. Closure is in layers.

Dr. John F. LeCocq [23] discussed the lateral approach, as described by Gibson, which he uses in almost all his arthroplasties and prosthetic operations. He pointed out that the disadvantage of severing the glutaeus medius and glutaeus minimus from the greater trochanter and then resuturing them lies in not being sure that secure reattachment occurs. However, removal of the trochanter lessens the danger of injury to the sciatic nerve which may occur on external rotation of the hip when the trochanter is in place. He re-emphasized that when the neck is short a downward transplantation of the trochanter should be done.

Unstable Internal Fixation of Intracapsular Fractures of the Neck of the Femur of the Adduction Type. Dr. Max Scheck [24] stated that healing of this type of fracture occurs by endosteal-callus formation, and stable immobilization of the fragments is necessary. In spite of adequate pinning, a shift in the anteroposterior or lateral, or both, projections occurred in thirty-six of seventy-seven patients. Follow-up was possible in twenty-nine of the thirty-six. Non-union occurred in sixteen and union, in thirteen. Of the latter, nine had been reduced with the femoral head in valgus position and it is believed that this position was a stabilizing factor which offset the effects of posterior settling of the head. Five of the fractures with non-union showed excellent valgus position in reduction and pinning but there was a complete posterior collapse. Six ununited fractures had a Pauwels III obliquity or the head was rotated and, in addition, there was posterior settling in three. In four patients with non-union, there was marked comminution of the inferior cortex of the neck of the femur; three of these patients also had posterior cortical fragments.

The author concluded that, in addition to Pauwels obliquity, another factor, posterior comminution at the fracture site, must be present to add instability. This usually manifests itself by the presence of a separate cortical butterfly fragment. The fracture is considered a compression fracture with posterior cortical or cancellous comminution and, regardless of the type of internal fixation, a certain number of failures will occur.

The author gave indications for closed reduction and pinning, open reduction and pinning, secondary osteotomy, and primary endoprosthesis. The number of primary osteotomies in this series was too small to permit a conclusion, but it appears that stable engagement of the head by a metallic pin is often not successful because of posterior comminution.

In his discussion, Dr. Merrill Mensor [25] stated that Dr. Scheck had drawn three important criteria to our attention that directly influence the prognosis in this particular type of fracture. They are:

1. Stability of fixation of the fragments;
2. The importance of compression versus shearing forces; and
3. Posterior comminution of the fracture as a cause of instability, rotation, and lack of union.

The fate of many fractured femoral necks is sealed at the time of initial trauma when the circulation of the head is destroyed.

Dr. Donald E. King [26] emphasized that impaction of the fragments at the time of operation will assure a greater number of unions.

Combined Use of Hip Prosthesis and Acetabular Construction in Correcting Deformity of Septic Arthritis in Infancy. Dr. Paul A. Pemberton [27] reported on three infant patients with septic arthritis of the hip with loss of the head and neck of the femur treated by prosthesis. Dr. Pemberton felt that arthrodesis is not a satisfactory solution to this problem in children. In the first case, a two-year-old child had lost the head and neck of the femur from infection during the first few weeks of life. A Vitallium femoral-head prosthesis (Thompson), seven-eighths of an inch in diameter, was inserted. Because of the shallow, sloping acetabulum, the

23. 1011 Summit Avenue, Seattle 4, Washington.
24. 240 Stockton Street, San Francisco, California.
25. 490 Post Street, San Francisco, California.
26. Stanford Hospital, San Francisco, California.
27. 220 Boston Building, Salt Lake City, Utah.

femoral head did not remain within the acetabular cavity. Eleven months later the acetabulum was deepened by reaming and the prosthesis was inserted in contact with cancellous bone. Three and a half years later he had a good, usable, almost painless, stable hip with two inches of shortening, and motion only in flexion.

The second case was that of an eight-year-old girl with a history of septic arthritis during the first few months of life. A Moore prosthesis was inserted without deepening the acetabulum. The hip is free of pain with a good range of motion and she is able to walk without a limp; however, roentgenographic examination showed a very shallow acetabulum and possible eventual instability.

The third case was a four-year-old boy who had lost the head and neck of the femur from infection before he was one year old. A Moore prosthesis, three-quarters of an inch in diameter, was inserted into the acetabulum and the acetabular roof was rotated outward in a manner described by the author at the meeting of The American Academy of Orthopaedic Surgeons in February 1958. The result is now a stable hip with a good range of motion and no pain. Dr. Pemberton believed that it is necessary to retain the articular cartilage of the acetabulum when a metal prosthesis is inserted to assure continuing motion in the hip in this type of prosthesis in children.

Dr. Philip H. Moore [28] stated, in his discussion, that he was impressed with the possibility of this operation in the reconstruction of septic hips in children because of the difficulty of fusion in childhood and loss of growth in the area.

The Effect of Isoniazid in the Healing of Fractures. Dr. A. W. Stevenson [29] and Dr. A. R. Allen [30] reviewed cases of spine fusion for tuberculosis in which isoniazid had been used. The authors noted early fusion in comparison with those in which no isoniazid was used. Other changes, seen in roentgenograms, were increased calcification of the femoral vessels, early calcification of the femoral vessels, early calcification of miliary pulmonary lesions, and a significant incidence of coronary occlusion following antituberculosis therapy with this drug.

Blood studies of fourteen male patients who received isoniazid therapy showed a cholesterol increase of between twenty-five and seventy-five milligrams per 100 milliliters of blood serum in twelve of the fourteen. There was also a decrease in serum calcium between the third and ninth week, with a return to normal after twenty-four weeks, and an increase in inorganic phosphatase up to the fifteenth week, with a return to normal by the twenty-fourth week.

These changes suggested the possibility that isoniazid was a stimulant to calcification of bone and might promote fracture healing. Seven patients who had non-union or recent hip fractures were placed on a daily regimen of four milligrams per kilogram of body weight for three months.

In a fracture of the left femur and tibia in a woman, forty-five years old, the femur readily healed but the tibia did not show healing eight months later. Isoniazid therapy was instituted at seven months after injury. Bone-grafting was done at eleven months. Two months after that the cast was removed and weight-bearing begun.

A second patient whose tibia was fractured in April 1957 had a sliding bone graft and plating six months later. This was followed by isoniazid therapy. One year after trauma, walking without support, she fell and fractured the opposite femur, without injury to the tibia.

The Deforming Effect of Tonic Reflexes of the Foot. Dr. William R. Duncan [31] indicated that during the course of a study of the distribution of contractures in cerebral palsy, he investigated the possibility that these typical patterns of deformity are caused by repeated stimulation of abnormal or unsuppressed reflexes. The results of these studies suggest that the abundant reflex activity in the foetus and newborn infant, if not integrated or suppressed in an orderly manner by an adequate upper neuron system, may contribute to deformity in the normal as well as the palsied child. Four separate tonic reflex movements can be elicited in the normal newborn infant by appropriate stimulation of four discrete areas on the surface of the foot. These reflexes gradually become unobtainable in an orderly sequence during the first years of life, and it would appear that their timely disappearance is due to a suppressive effect exerted by the maturing central nervous system. If suppression is delayed or disorderly, allowing abnormal persistence of a single reflex, random environmental stimuli are sufficient to cause the foot to assume habitually the attitude of the reflex movement. Fixation of the foot in this reflex-induced position may eventually occur. In the normal infant such reflex imbalance appears to account for the several transient foot deformities which occur during the first year of life. Fortunately, these deformities tend to disappear, with or without treatment, during the subsequent years when all such reflex activity is eventually suppressed.

28. Sitka, Alaska.
29. 7 South Tenth Avenue, Yakima, Washington.
30. Selah, Washington.
31. 1607 Medical-Dental Building, Seattle 1, Washington.

In the child with brain damage and impaired suppressive ability, these reflex imbalances may persist for years and lead to serious fixed deformity. Thus, a general understanding of tonic reflex activity becomes pertinent to the orthopaedic evaluation and management of certain common foot deformities. A knowledge of normal sequence of suppression offers a further basis for evaluating the maturity (suppressive ability) of the central nervous system.

In his discussion, DR. G. W. COTTRELL[32] stated that he had been able to corroborate the existence of these reflexes in his clinic. In patients with mild cases of cerebral palsy and in very young children, testing for retention of other reflexes has a definite value. Simple failure of suppression is probably not the whole explanation of retention. He felt that every advance in our understanding of these problems should be encouraged.

Local Ischaemic Necrosis of the Leg. DR. IVAR J. LARSEN[33], DR. EDWARD W. BOONE[34], and DR. ELLIOT L. COLES[35] stated that localized ischaemic necrosis of the leg is a frequent occurrence in traumatic and orthopaedic surgery. They felt that the condition is frequently overlooked in the early stages because of overlying casts.

The authors presented three cases of ischaemic necrosis of the anterior compartment of the tibia which developed after common orthopaedic procedures, tibial pinning, rotational osteotomy, and tibial-plateau fracture in three patients aged fifty-five, thirty-five, and two, respectively.

The frequency of occurrence and difficulty of diagnosing localized necrosis in a patient wearing a cast was emphasized. The authors felt that the importance of systemic reaction to muscle necrosis, with particular attention to symptoms suggestive of various degrees of lower-nephron nephrosis, should be watched for.

Presidential Address. DR. JOE B. DAVIS[36] delivered the Presidential Address, which was both scholarly and humorous, admonishing the members to have prudence, fortitude, temperance, and justice. He described some surgeons by comparing certain similarities to species of migratory birds.

He cited the historical interest of men in the cyclic appearance and disappearance of ducks and geese, and reviewed the writing of diverse ancient pundits on this phenomenon. The several routes followed by these birds during their flights over this continent were delineated. The efforts of the meat hunters, or professional bird killers, to extinguish the edible water fowl were exposed with suitable illustrations of various multibarreled and scatter guns which these miscreants employed.

Dr. Davis pointed out the salient characteristics of certain species of ducks. The baldpate, or widgeon, is retiring, with a soft voice, an irritable disposition, and an indecisive personality.

The spoonbill, or shoveller, is known for his tremendous beak, his irritating and raucous chatter, and his repulsive, gluttonous eating habits.

The pintail, with his powerful wings and long neck, which enable him to poke his head into everyone's business, cuts and slices his way through life without regard for the feelings of others.

The stately and stable mallard is the gracious gentleman among the ducks. His well modulated voice and pleasant manners match his kindly disposition.

A strong resemblance to these types of ducks is sometimes shown in certain of our contemporaries. Indecisive baldpateitis, nervousness, and unreliability may be observed among those orthopaedic surgeons whose reiterated "I'm not sure", and "Let's wait and see" prevent their meeting problems in a forthright, firm manner.

Shovellerism is manifested by gluttonous and constant ingestion of food, interspaced with vocal eructations. The latter are commonly misinformative and unrelated to the immediate problem.

Pintailism is fortunately decreasing among us but occasionally one is confronted by the bombastic, overconfident, knife-happy surgeon whose sovereign remedy is to cut, regardless of symptoms or diagnoses.

Dr. Davis concluded by hoping that, with the help of our Lord, we can all aspire to the gentle serenity, humility, stability, and kindliness of the mallard.

Experiences with a Cervical-Spine Fusion. DR. HOWARD L. CHERRY[37] reported a series of six cervical-spine fusions done by the usual posterior approach. These fusions were occasioned by the residual changes of fracture in all but one patient who had symptomatic congenital spondylolisthesis. The level of fusion is carefully selected; a lateral roentgenogram is made in the operating room to confirm this level. Only the vertebrae directly involved are fused. The spinous processes and laminae are carefully exposed and surfaces roughened. Iliac bone is used as a graft. Number 00 woven stainless-steel wire is then used to immobilize the fused

32. 444 Medical Arts Building, Portland, Oregon.
33. 1133 Punchbowl, Honolulu 13, Hawaii.
34. 1154 Bishop, Honolulu, Hawaii.
35. 208 East Wisconsin Avenue, Milwaukee 2, Wisconsin.
36. Standard Insurance Building, Portland, Oregon.
37. 812 S.W. Washington Street, Portland 5, Oregon.

vertebrae and to hold the graft in place taking care to avoid dissection or placing any donor bone beyond the level of the fusion. The posterior articulations are not opened and care is taken to stay posterior to the mid-line of the laminae. It is essential to use very sharp instruments to avoid excessive trauma. Fusion was solid in all six in a reasonably short period of time. Two case reports were presented in detail.

In discussing the paper, DR. CHESTER MCREYNOLDS[38] and DR. VERNON NICKEL[39] pointed out that the indications for cervical-spine fusion are basically all secondary to an undesirable instability of the neck. This instability may be due to trauma, to congenital abnormalities, extensive surgical laminectomy, extensive paralysis caused by poliomyelitis, or painful conditions such as extensive osteo-arthritis with nerve-root irritation that has been adequately decompressed. Dr. McReynolds presented a slide showing the halo which they have developed to maintain adequate positioning and positive control of the skull. Their results, in a total of sixty-two cervical-spine fusions done since 1956 at Rancho Los Amigos Hospital, have been favorable utilizing either the anterior or posterior approach.

Surgical Treatment of Severe Radiculitis Arising from Nerve-Root Compression and Irritation in the Cervical Spine. DR. GERALD G. GILL[40] and DR. HUGH L. WHITE[41] presented their experiences in the surgical treatment of severe and persistent radiculitis due to nerve-root compression and irritation in the cervical spine. This group included eighteen patients operated upon from 1952 to 1958. They emphasized that during the same period of time they had operated upon three hundred, or more, patients with conditions of the lower portion of the back and it was their opinion that during this period they had seen as many patients with acute neck difficulty as with acute low-back difficulty. Most patients with acute symptoms of the neck respond to simple conservative measures consisting of hospitalization with neck traction, followed by the use of a simple neck-traction apparatus at home at night or the use of a brace with careful attention to posture and corrective exercises.

The authors have approached the surgical treatment carefully and have operated upon only those patients who have not responded to conservative treatment or in whom the pain had been so severe after conservative treatment that operative intervention appeared mandatory. The surgical procedures used have included simple laminectomy, hemilaminectomy, interlaminar laminotomy resulting in hemifacetectomy at one or two levels, and fusion at the time of the original surgical exploration. The authors felt that the changes which appear in the lateral intervertebral joints and articulations are secondary to primary discogenetic degeneration; this may be the result of premature aging, injury, or stress. At any rate, with the narrowing of the disc and proliferative changes posteriorly, there are proliferative changes at the lateral intervertebral joints and a build-up of the anterior bar. The nerve root, in passing across the lateral intervertebral joint, is compressed by proliferation in this area from in front and by anterior proliferation from the zygapophyseal articulation behind. Once the hard bone structure, caused by the medial half of the posterior articulation, is removed, along with the ligamentum flavum, the root is no longer held firmly against the lateral intervertebral joint and can displace posteriorly, thereby relieving its compression. The authors found lateral herniation of the disc to be uncommon, frank herniation being present in only two patients and protrusion of the disc present in one of their group of eighteen. In the other patients, compression was apparently caused by arthritic spurring. The level was determined by the patient's symptoms, roentgenographic findings, and myelograms. The authors presented detailed case reports of the eighteen patients operated upon.

They concluded that surgical intervention is necessary in the treatment of severe and intractable radicular pain arising from nerve-root compression and irritation in the cervical spine in few patients and that surgical procedures through the posterior approach have been safe and not difficult from the technical point of view. All of the patients with severe, unrelenting pain were relieved. On the basis of their most recent experience, arthritic patients who had local fusion, with the use of local bone at the time of surgery, had fewer recurrences and less tendency for local neck pain to continue than those in whom fusion was not performed. Simple laminectomy, hemilaminectomy, and interlaminar laminotomy or hemifacetectomy on both have been successful, however, in relieving acute, lancinating pain.

In the discussion, DR. HOMER C. PHEASANT[42] pointed out that, in his practice, he has about four times as many patients complaining of back problems as neck problems. Of the patients treated during 1951 and 1952, he performed forty-five surgical procedures on 468 patients with symptoms in the lumbar spine, whereas no surgical procedures were carried out on the 111 patients with pain in the cervical spine, although three were referred to a neurosurgeon for neurosurgical treatment in the past nine years. Dr. Pheasant recognized the frequency of anterior bar and osteophyte formation in the cervical area and felt that both areas

38. 7847 East Florence Avenue, Downey, California.
39. 1700 Brooklyn Avenue, Los Angeles 33, California.
40. 516 Sutter Street, San Francisco 2, California.
41. 516 Sutter Street, San Francisco 2, California.
42. 1401 South Hope Street, Los Angeles 15, California.

should be equally amenable to surgical relief. He emphasized the feeling, however, that spine fusion should be added to decompression, as implied by the authors in their more recent experience.

Experiences With Anterior Interbody Spinal Fusion. Dr. Paul H. Harmon [43] reported 180 patients who had abdominal extraperitoneal disc-excision operation followed by body-to-body bone-grafting in the lower lumbar vertebral area. Of these, 120 were analyzed in detail. These data indicate osseous union in 82.8 per cent of the patients in the earliest group (followed ten years) who had vertebral spaces operated upon and in 98.8 per cent of the ninety patients more recently operated upon by an improved technique.

The author stressed the importance of evaluating the pathological condition of the disc during surgery by carefully watching the capacity of controlled injections of saline. The improved operative technique in the later patients included more complete removal of the annulus fibrosus and the use of both cortical and cancellous bone, the former impacted after the cortical osseous plates are excised. The author felt that previously expressed fears that an intraspinal fragment left in the canal would cause continued trouble should no longer exist because of the total practical experience. He stated that almost every patient is free of radicular pain upon awakening from anaesthesia. Relief from lumbago is obtained in the average time of six weeks. Hospitalization lasted usually for ten days, and the average time until return to work is twelve weeks. Patients in sedentary occupations have returned to work in three or four weeks.

The author concluded that this operation is safe and reliable for relief of lower lumbar-disc syndromes, either as a primary or as a salvage operation. The period of hospitalization and amount of disability of these patients compared favorably with those who had the most advanced technique of posterior spine fusion.

In the discussion of the paper, Dr. Charles G. Hutter [44] emphasized the advantages of interbody fusion and related his experiences with interbody fusion by the posterior approach.

Flailness of the Lower Extremities in Poliomyelitis. Dr. Charles L. Lowman [45] stated that the problems presented by severe paralysis of the lower extremities require careful consideration and analysis with regard to the possible reconstructive and rehabilitational procedures. There are three types of patients with flaccid lower extremities: (1) those paralyzed from the waist down; (2) those with a fairly good trunk, but both lower extremities flail; and (3) those with one lower extremity flail, or nearly so, and the other normal or only partially involved. In patients in the first group, the major consideration is to obtain stability in sitting. Criss-cross fascial transplants in front from the costal margin to the opposite ilium, followed by running lateral transplants from the greater trochanters to the tenth ribs, will give sufficient trunk stability to allow the arms and hands to be used effectively. Many patients in the second group with a good trunk but severely involved lower extremities can be made to stand in braces but, fitted to full-length ischial bearing ring splints, they may not be able to lift the extremities for stepping. In this case, bilateral fascial transplants from trochanter to ribs and trochanter to latissimus dorsi give patients a pick-up on one side and stabilize the standing extremity to a reasonable extent. Stabilization of the feet and ankles seems to make the patients feel better, even when in braces. Patients in the third group with unilateral flailness of the lower extremity can frequently be greatly helped by having panarthrodesis and lateral fascial transplants of the hip performed. Fascial strips are also of value in patients who have no hip flexion but who have good upper abdominal muscles where a strip is run from the upper rectus to the leg, transmitting a fair lift and some flexion which advances the leg for stepping with rotation on the opposite hip.

Dr. Eldon G. Chuinard's [46] discussion and tribute to Dr. Lowman brought a vote of acclaim. His discussion, verbatim, was as follows:

It is a great privilege to be invited to discuss a paper of Dr. Lowman's because one is put in that pleasant, yet difficult, position of not needing to seek words to express unfavorable criticism, yet not being able to find the sought-for words to express adequately the complimentary regard that is due him and his work.

In this day of high-level performance from a specialty such as ours, it is most difficult for any orthopaedist to originate and perfect a new and enduring contribution. We have just heard a paper from one who has done that very thing. Through many years of careful work he has perfected the technique of what has become an orthopaedic household term, the *Lowman transplant*, and has outlined very clearly the indications for use of this procedure. His first work in the field of fascial transplants was done in 1931, and the ensuing years have added to his stature as the master in this field. Therefore, it would be very presumptuous of me to attempt to offer a critical analysis of his work.

43. 2425 Geary Boulevard, San Francisco 15, California.
44. 6753 Hollywood Boulevard, Hollywood 28, California.
45. 2417 South Hope Street, Los Angeles 7, California.
46. 1922 N.W. Johnson, Portland 9, Oregon.

In reviewing every article that he has written on this subject, I have been impressed, not so much by the emphasis on surgical techniques, as by the emphasis Dr. Lowman has placed upon the careful analysis of the kinetic potential of each case, a diligent pursuance of a graded preoperative and postoperative program of excercises to develop the maximum balanced potential of muscles, the individualized attention to gait training, and a careful explanation to the patient of what to expect from the procedure. He has emphasized the importance of obtaining trunk stability as preliminary and basic to proper ambulation, in order to prevent erroneous and deleterious habits of posture and gait.

Dr. Lowman has mentioned in his paper other procedures which contribute to decreasing the instability of the lower extremities, such as arthrodesis, a procedure in which I have had more personal experience. Adding ankle fusion to triple arthrodesis is most important to those cases where maximum stability is desired and agility cannot be expected anyhow. The ankle fusion is often delayed in growing children because of the potential damage to the distal tibial epiphysis, and thereby many years of a more secure gait with less brace encumbrance is denied the patient. It is in this regard that I may offer a suggestion.

We have done a few ankle fusions by removing the articular cartilage and impacting a wedge of bone from the ilium, fashioning the mortise and the wedge so as to gain a desired degree of plantar flexion to compensate for shortening. The distraction provided by the wedge secures a firm impaction that is otherwise difficult to obtain in the ankle joint. Fusion occurs rapidly and we have noted no damage to the tibial epiphysis.

You may have perceived that these remarks have constituted more of a discussion of Dr. Lowman than of his paper. If that be your impression, then I have made my point. For how can anyone who will always remain a neophyte offer a critical comment on the master? Therefore, I followed a procedure that has become customary in our office: I passed Dr. Lowman's paper around for the other men to read and comment on, and I would like to pass on to you and to Dr. Lowman the remarks of Dr. Leo Lucas who is in a better position than I to offer a proper judgment. "I have heard some of his papers and results which have always been impressive. He is the master and the only authority on this phase of surgery. No one has ever tried to criticize, add, or detract when discussing his papers, but only has had praise and great admiration for his great contribution to orthopaedic surgery."

I was impressed at the standing ovation given Dr. Lowman at the recent meeting of The American Orthopaedic Association and more impressed by the remarks of this venerable scholar —remarks touched with the wisdom and history of many years and the kindliness of a great gentleman. Dr. Lowman, I know that in this audience are many old friends and admirers who enjoyed hearing your words again and many young men who thrilled at seeing and hearing one of the master teachers of orthopaedics. I know that all of us here in the Northwest sincerely hope that you will visit us again when the Western Orthopedic Association comes our way again.

Screw Fixation of the Non-United Carpal Navicular. Capt. W. R. Miller [47] discussed McLaughlin's method of treating non-union of the carpal navicular which he used in twenty-four Navy personnel. The method of treatment included radial styloidectomy to facilitate placing the impacting screw and to reduce the available fulcrum against which the navicular is forced during use of the hand and wrist. He made a comparison with results he obtained by previously used conventional methods and with figures presented in a survey made for the National Research Council by Dr. Joseph Barr of Boston.

The results of four of the twenty-four patients were considered failures. Two of these needed arthrodesis; one was lost in follow-up, although he returned to duty with subjective complaint; and the fourth had the screw and osseous fragments removed elsewhere—rheumatoid arthritis complicated the result in this patient. Capt. Miller's presentation and evaluation of results was based on clinical symptoms; no claims were made as to the per cent of union which took place.

Both the author and the discussor, Dr. Keene O. Haldeman [48], emphasized the fact that, with proper early diagnosis and immobilization, union can be expected and results excellent without internal fixation.

Shoulder Arthrography. Dr. Robert L. Samilson [49] and Dr. Frank L. Raney, Jr. [50] presented a detailed description of a method of shoulder arthrography. The arthrographic findings made of normal shoulders by this method were described in detail. The method was applied to 103 shoulders without resultant infection. The authors felt that the method is safe, easy, and may be done in the out-patient department. Consistent pathological patterns were demonstrated by excellent slides in tears of the rotator cuff, in bicipital lesions, in shoulder dislocations, and in frozen shoulders. Studies, particularly in cine-arthrography, are being continued by the

47. United States Naval Hospital, United States Naval Station, Long Beach, California.
48. 350 Post Street, San Francisco, California.
49. 490 Post Street, San Francisco, California.
50. 3635 California Street, San Francisco, California.

authors and it is their hope that much more will be learned about shoulder-joint function and pathology in future studies.

DR. LOUIS H. EDMUNDS[51], in discussing the paper, emphasized the difficulties which may be encountered in entering the shoulder joint and the ease with which the dye can be injected outside the shoulder joint. He also emphasized that experience is necessary in interpretation of the arthrograms. He likewise verified the authors' feeling that it is a good test especially in tears of the rotator cuff.

WESTERN ORTHOPEDIC ASSOCIATION ANNUAL AWARD RESIDENT ESSAYS

The Relative Importance of Periosteum and Blood Supply in Fracture-Healing. DR. L. C. FOLKES[52] attempted to determine the relative importance of periosteum as compared to blood supply in fracture-healing. Experiments were performed on forty rabbits in which fractures of the humerus were produced; subsequent studies lasted for from two to six weeks.

Uniformity and simplicity of technique were obtained by producing, with a saw cut, an incomplete fracture which extended across one-half the diameter of the rabbit's right humerus and subsequently amputating the foreleg. The animals were sacrificed and the humerus dissected out *in toto*. The amount of fracture healing was determined by gross inspection, roentgenograms, photographs, and microscopic sections.

The experiment was divided into three major groups: (1) A control group with saw cut only. The results showed rapid healing in two to three weeks. (2) Following the saw cut, the periosteum was elevated and kept separated from the shaft by wrapping it with tantalum foil. The amount of blood supply to the fractures was varied by interrupting either the periosteum, the medullary, or the nutrient artery supply. Delayed or poor fracture healing at six weeks, death of the cortex of the shaft, and marked involucrum bridging the tantalum foil resulted. (3) Following the saw cut, the periosteum was left intact with the bone but separated from the surrounding soft tissue by tantalum foil. The variations of blood supply corresponding to Group 2 were done. Fracture healing in about three weeks, viable cortical bone, and markedly thickened periosteum often showing new and hypertrophied network of blood vessels resulted.

As a result of this experimental work, the inference is drawn that fracture healing is essentially dependent upon the presence of periosteum at the fracture site. Furthermore, the time of fracture healing varied inversely with the adequacy of blood supply to the injured area.

Pathomechanics of the Knee Joint. DR. ALBERT F. MARTIN[53] reported the results of his investigation of the feasibility of stress testing the medial collateral ligament of the knee in the presence of fractures of the lateral tibial plateau. Fresh specimens amputated through the mid-portion of the thigh were utilized for the production of fractures of the lateral tibial plateau. Stress testing was then performed with the limb in the valgus position with and without ligamentous damage. The specimens were fixed in a wooden wedge mount and three sets of abduction-stress roentgenograms were made of each specimen. The first was made with intact bone and ligamentous structures; the second, after resection of the lateral tibial plateau and its meniscus; and the third, after resection of the medial collateral ligament.

Review of these experimental stress films revealed the following: (1) Increase in the medial clear space, following plateau resection alone, is minimal—less than one centimeter. The author concluded that significant opening of the medial clear space will not occur with plateau injury alone. (2) When there is a demonstrable increase in the medial clear space—greater than one centimeter—there must be damage to the medial collateral ligament. The experimental work cited is correlated with clinical observations on patients diagnosed as having injuries to the lateral tibial plateau and medial collateral ligament.

Recommendation was made for abduction stress testing with roentgenographic control on patients having injuries to the knee joint. Where valgus instability is readily demonstrable, early surgical repair would seem indicated. The essential data obtained from cadaver specimens has, however, primarily experimental implications.

Cavus Deformity of the Foot. DR. WILLIAM D. GUYER[54] and DR. CHARLES A. FAGAN[55] expressed concern over the importance of early and vigorous treatment in the prevention of progressive cavus deformity of the foot. Although the components of the deformity may vary, classically, the cavus foot presents a fixed high arch with moderate varus position of the fore part of the foot, hyperextension of the metatarsophalangeal joints, and flexion of the proximal interphalangeal joints. In addition, equinus position of the hind part of the foot may be present, although paralytic calcaneus deformity has also been noted.

51. 1118 Ninth Avenue, Seattle 1, Washington.
52. 4800 Sand Point Way, Seattle, Washington.
53. University of California Medical School and Samuel Merritt Hospital, Oakland, California.
54. Shriners' Hospital for Crippled Children, Portland, Oregon.
55. Shriners' Hospital for Crippled Children, Portland, Oregon.

Etiological factors include intrinsic-muscle weakness, muscle imbalance, and congenital deformities. In many cases, the common denominator of the several mechanisms seems to be contracture and shortening of the plantar fascia and ligaments. When the deformity is progressive and conservative treatment with anterior heels, exercises, and night splints is of no avail, plantar soft-tissue stripping would seem to be indicated. The importance of a lateral surgical approach was emphasized in order to avoid medial scarring and recurrence of the deformity.

This study was conducted at the Shriners' Hospital for Crippled Children, Portland, Oregon, from July 1952 to July 1958. Operations were performed on fifty-three feet in forty patients. The average age was ten years, with a range of from four to fourteen years. In forty-eight feet, improvement was obtained and in five feet, no improvement was noted. Only two complications were reported; one instance of incisional skin loss and one pressure ulceration caused by plaster.

Prosthesis Arthroplasty of the Hip. Dr. William E. Burkhalter[56] and Dr. Sheldon Roger[57] summarized their experiences with prosthetic arthroplasty of the hip at the University of Colorado Medical Center. From 1951 to 1957, 127 arthroplasties of the hip were performed on 120 patients treated in the hospitals of this medical center. The preoperative indications for surgery were: failure of primary treatment of femoral-neck fractures, primary treatment, *per se*, of femoral-neck fractures, degenerative arthritis, previous unsatisfactory arthroplasty, rheumatoid arthritis, and miscellaneous diseases.

The largest single group of patients (sixty-two) on whom the operation was performed had complications following fractures of the neck of the femur. Replacement arthroplasty was utilized as a primary treatment of femoral-neck fractures in forty-two instances.

Adequate follow-up examinations were obtained in eighty-six patients with ninety-two operations. The average length of follow-up was 23.5 months. During the follow-up evaluation, grading was made on a functional basis and divided into four categories: *excellent, good, fair,* and *poor*. The most desirable results were in those patients who had full activity and no limp or pain; the least desirable result occurred in patients who had constant pain and required crutches for support.

In this group of eighty-six patients, the results of twenty-seven were graded *excellent;* twenty-nine, *good;* seventeen, *fair;* and nineteen, *poor*.

Complications most frequently encountered in this series included fracture of some portion of the femur at the time of insertion of the prosthesis, wound infection, and postoperative dislocation of the prosthesis.

Significantly, the authors felt that better results are obtained when prosthetic arthroplasty is utilized for the treatment of complications of femoral-neck fractures rather than for the primary treatment of these fractures.

Non-Union of Fractures of the Trochanteric Area of the Femur. Dr. Howard R. Baker[58] studied eleven patients with ununited intertrochanteric fractures of the femur. The author stated that non-union of intertrochanteric fractures of the femur is rare and that this complication is largely ignored in the literature. The ages of the eleven patients analyzed ranged from fifty-seven to ninety years.

All types of intertrochanteric fractures were represented in the series. The predominant area of non-union, however, was in the region of the lesser trochanter especially when a nearly transverse fracture line existed in this region. In the fractures treated by traction, the outstanding contributory factor in the development of non-union appeared to be distraction of the fracture with resultant inadequate contact which, in one case, was associated with too vigorous an attempt to correct a varus deformity.

In the surgically treated fractures, one case was characterized by too early removal of the nail with subsequent medial migration of the femoral shaft. In the other cases, unstable fixation appeared to be a major contributing factor in producing non-union. The author felt that if internal fixation is not completely stable at surgery, additional fixation such as a plaster hip spica or light traction should be employed. Medial migration of the femoral shaft, allowing the inferior cortex of the neck to pass over the medial cortex of the shaft fragment and to abut its lateral cortex, was a common finding in this series. It occurred in patients treated by both traction and surgery. Surgical correction of non-union consisted in internal fixation and bone-grafting procedures with or without an abduction osteotomy. In the majority of patients followed this operation was successful. No valid statistical conclusions could be drawn, however, because of the small number of patients reviewed.

Reconstruction of the Spastic Hand. Dr. James N. Wilson[59] evaluated the diagnostic

56. University of Colorado Medical Center, Denver, Colorado.
57. University of Colorado Medical Center, Denver, Colorado.
58. Veterans Administration Hospital (Sawtelle), Los Angeles, California.
59. 1401 South Hope Street, Los Angeles, California.

and therapeutic approach to the surgical management of disability resulting from the spastic hand. Reconstructive soft-tissue surgery for spasticity of the upper extremity has generally been regarded with disfavor. However, the patient with cerebral palsy should be differentiated from the individual suffering from spastic paralysis following brain or cervical-cord damage. Such distinction should be made both from the degree of spasticity and the surgical prognosis.

In cerebral palsy, the spasticity is frequently generalized and the patient has little, if any, voluntary control over any specialized muscle groups. Attempts at active motion are usually accompanied by mass reaction in which the spastic elements determine the position of the hand and wrist irrespective of the patient's volition. In cases of post-traumatic spasticity, however, the patient retains control of specific muscle groups and loses only voluntary control of selected areas. In such cases the selective use of tenotomy, tendon transfer, tenodesis, and neurectomy may be useful in improving hand function.

This report was based upon four patients in whom some improvement in hand function was accomplished by reconstructive surgery.

Dr. Wilson emphasized that spasticity, *per se*, is not an undesirable element and that, prior to any surgical approach, the expected improvement must be carefully evaluated against the possibility of diminished function following surgery.

Dr. William R. Duncan [60], in his discussion, emphasized the distinction between the congenital and acquired types of spastic hand, since the surgical approach may be entirely different for each type. Many of the mass reflexes occurring in patients with spasticity represent protective mechanisms which should not be altered by surgical interference.

Experimental Data on the Healing of Ruptured Ligaments. Dr. Mack L. Clayton [61] and Dr. Gordon J. Weir [62] reported the results of an experiment testing the comparable tensile strength and microscopic picture of divided ligaments treated by simple immobilization and those treated by open surgery and suture. Their work was based on the premise that, following complete rupture of a ligament, instability of the related joint often occurs because the ligament fails to heal with proper length and strength following conservative plaster-immobilization technique.

The experimental procedure was as follows: The medial and lateral collateral ligaments of the knee were horizontally transected at the joint line in twelve adult mongrel dogs. The ligaments in one leg were sutured; those in the other leg were left open. Groups of dogs were sacrificed at intervals of four days, and one, two, three, four, and six weeks, postoperatively. The ligaments were examined grossly and microscopically and tensile-strength determinations were carried out. It was found that the tensile-strength determination of the sutured ligament was stronger than the open ligament at all test periods and that the sutured ligament regained normal strength in six weeks whereas the unsutured ligament did not regain normal strength even after that period of time.

The authors concluded that recovery with better strength and stability of the joint results after primary suture of a completely ruptured ligament than after simple plaster immobilization.

Dr. Kirk J. Anderson [63], in discussing this experiment, stated that this study rendered an answer of practical importance in the treatment of the freshly ruptured ligament. In his experience, primary surgical repair of a severely ruptured ankle ligament, involving both the anterior talofibular and calcaneofibular ligaments, assured superior results. This impression was also confirmed by experimental laboratory observations of an anatomical nature. His impression was that conservative management of the completely ruptured ligament does not assure accurate repositioning of the displaced segments after restoring joint alignment.

Intervertebral-Disc Space Infective Processes. Dr. Thomas B. Scanlon [64] and Dr. John J. Loutzenheiser [65] drew attention to a clinical entity which has been variously labeled as non-specific spondylitis, spondylarthritis, a benign form of osteomyelitis, acute purulent infection of the intervertebral space, destructive lesions of the vertebral disc, infection of the vertebral interspaces, and vertebral osteomyelitis. This disease has not received adequate coverage in the orthopaedic literature, but has been noted with greater frequency in literature pertaining to urology and roentgenology. An intervertebral-disc space may become infected by direct arterial infection, by venous implantation from pelvic and genital-organ drainage, by way of the plexus of Batson, or by direct contamination following lumbar puncture, open surgery, and other iatrogenic means.

Usually the orthopaedist is consulted late in the course of the disease, characterized by

60. 1607 Medical-Dental Building, Seattle 1, Washington.
61. 83 East 18th Avenue, Denver 18, Colorado.
62. United States Naval Hospital, Norfolk, Virginia.
63. 1011 Summit Avenue, Seattle 4, Washington.
64. 2020 Hayes Street, San Francisco, California.
65. 2020 Hayes Street, San Francisco, California.

pain and limitation of motion in the back with roentgenographic findings of narrowing of the intervertebral-disc space, reactive sclerosis of the adjacent vertebrae, and, in some cases, actual destructive lesions involving the vertebral components.

The authors emphasized that the diagnosis of infection of the intervertebral-disc space is materially aided by vigilant awareness of the existence of the disease. Biopsy of the vertebra may be necessary when the diagnosis is in doubt.

Primarily conservative treatment, including wide spectrum antibiotic therapy and immobilization of the spine by plaster jacket or brace should be the rule. Occasionally, surgical decompression of the interspace may be necessary to relieve pain or to drain a frank abscess cavity. In those patients in whom spontaneous interbody fusion does not occur, surgical arthrodesis may be necessary.

Dr. Harold Crowe [66], in his discussion, recalled his experience with a child, aged twelve, who had been followed for approximately nine years. Inasmuch as spontaneous interbody fusion is considered desirable, Dr. Crowe postulated that the extensive use of antibiotic therapy might prevent the occurrence of such spontaneous healing.

Arthrodesis of the Knee with Intramedullary Fixation. Dr. Robert Mazet, Jr. [67], and Dr. Marshall R. Urist [68] stated that, following knee arthrodesis, immobilization may usually be assured by passage of a medullary nail of sufficient length and strength across the fusion area and the use of a toe-to-groin walking plaster.

The active compression of muscle pull and the intermittent compression furnished by ambulation promote early consolidation. Patients may sit in a wheel chair within a few days and walk with crutches in three to four weeks. Prolonged hospitalization is unnecessary.

The most common complications encountered with this method are: (1) fracture of the femur at the level of the nail insertion, and (2) fracture of the nail at knee level. Infection is not a frequent danger. Most failures occurred in patients with neuropathic joints.

A technique which reduces the danger of fracture of the femur was presented: A long carpenter's drill, one-half inch in diameter, is introduced retrograde into the femur from the distal end and a hole is drilled through the anterior cortex of the femur. The drill is withdrawn and the medullary nail is introduced retrograde through the drill hole. An incision is made through the skin at the point of emergence of the nail and is driven out through the skin until its lower end is level with the distal end of the femur. The tibia is then brought into apposition and alignment and the nail driven into the medulla of the tibia. Since the use of this technique, no fractures of the femur have occurred.

Medullary-nail fixation in fused knees has been shadowed by a great wave of enthusiasm for compression arthrodesis during the past decade. We believe medullary-nail fixation provides equally satisfactory immobilization. There is no external apparatus to get out of order or to adjust. There is no danger of pin-tract infection.

The authors reviewed forty-six previously reported cases of knee fusion with medullary-nail fixation. Twelve additional cases were reported and analyzed. Ten fusions occurred; there was one failure in a Charcot joint.

The authors believe that medullary-nail fixation in arthrodesis of the knee is a safe and satisfactory procedure when the technique suggested previously is used.

Dr. Roger Anderson [69], in discussion, advocated a type of compression using two Steinmann pins above and two below the knee, with turnbuckle or elastic traction.

The Stone Operation for Hallux Valgus. Dr. Robert Bingham [70] presented eighty-four clinical cases of hallux valgus and hallux rigidus and a technical description of the surgical correction as done by Dr. Charles Stone of St. Louis, Missouri. The operative technique consists in an oblique excision of the head of the first metatarsal, removal of the exostosis, and preservation of the plantar border of the first metatarsal shaft for weight-bearing on the sesamoid bones. The joint capsule is purse-stringed between the end of the osteotomized bone and the base of the first phalanx, producing a fibrous joint which corrects the deformity and still maintains good function and partial weight-bearing.

The toe is bandaged simply into a corrective position and full weight-bearing is started as early as the second postoperative day. In an end-result study of twenty-five private patients, representing fourteen bilateral and eleven unilateral operations, twenty-one had excellent functional and cosmetic results; four patients were improved but had some metatarsalgia in the region of the second and third metatarsal heads or stiffness at the first metatarsophalangeal joint. The author believes that the Stone operation is simple in technique, requires a short hospitalization, permits full weight-bearing, and has the shortest period of disability of any procedure yet devised for simultaneous correction of hallux valgus or hallux rigidus and exostosis of the first metatarsal head.

66. 635 South Westlake Avenue, Los Angeles 57, California.
67. Veterans Administration Hospital, Los Angeles 25, California.
68. 1019 Gayley Avenue, Los Angeles 24, California.
69. 509 Olive Way, Seattle 1, Washington.
70. 3536 10th Street, Riverside, California.

In the discussion of this paper, DR. CHARLES STONE [71] described his experience with this procedure in over fifty years of orthopaedic practice and in over a thousand operations. Although it had never previously been published, he claimed no originality for this technique. He agreed with the high per cent of satisfied patients and relative simplicity of the operative procedure.

DR. WARREN WHITE [72] also discussed the paper and recommended this procedure on the basis of twenty-five years experience with a similar technique. He agreed with Dr. Stone that early walking is the main secret of the success of this procedure over the more complicated technical operations which require prolonged periods of immobilization or restricted weight-bearing after surgery.

Leg-Length Equalization by Femoral Shortening. DR. M. JOHN ROWE [73] and DR. GUSTAVUS BOCK [74] presented a series of twelve cases of femoral shortening with intramedullary fixation after shortening osteotomy had been performed, the femoral shortening being done on the longer of the two extremities. The authors feel that the current tendency to correct leg-length inequality by epiphyseal arrest is hazardous since iatrogenic deformity may develop in the good leg with an unsatisfactory result because of the difficulty of predicting the future growth of a specific individual. Correction during growth by shoe lifts, progressive supervision of leg-length by Farill roentgenograms, and definitive shortening with intramedullary fixation until completion of growth has been satisfactory in their short series. They feel that this procedure is safer and more accurate than epiphyseal arrest. Their program of treatment is: (1) leveling-off the short leg with shoe lifts sufficiently to allow the patient to stimulate the short leg by equal pounding and walking comparable with weight-bearing on the opposite side; (2) checking growth regularly by clinical measurements and by Farill roentgenograms at about six-month intervals; and (3) differences in length of more than two centimeters for which normal lateral pelvic mobility cannot compensate are surgically corrected at or near the end of the growth period. A measured segment of femoral shaft is removed from the long side and a double-ended, diamond-shape, intramedullary nail is used for fixation until healing is complete. The pin is then removed after union is solid. The procedure is used for lower limb-length discrepancy in patients with poliomyelitis, septic arthritis, tuberculosis of the hip, and spastic paraplegia with old fracture. The average hospital stay for the operation is nine days. One complication of postoperative telescoping was described. All results were graded as good.

In discussion of this paper, DR. DANA STREET [75] pointed out that in addition to the previously mentioned methods of leg-length equalization described by the authors; namely, growth stimulation, growth arrest, bone-lengthening, and bone-shortening, a fifth method of lower-limb equalization by subtrochanteric osteotomy must also be kept in mind in such corrective surgery. Dr. Street pointed out that the desirability for equalizing the two limbs for weight-bearing is important toward restoring and maintaining improved motor function in limbs which are taking weight-bearing in a somewhat equal manner ,as well as the improvement in the bone structure itself in the shorter limb which can be anticipated by more or less even weight-bearing. Dr. Street emphasized the difficulty in controlling rotation of the transverse osteotomy, as described by the authors, and described his own technique for avoiding this at the time of performing the osteotomy.

Hemipelvectomy. A Review of Thirteen Cases. DR. ROBERT A. WISE [76] discussed his experience with thirteen consecutive patients with hemipelvectomy. There was no operative mortality. The indications for the procedure were: (1) primary malignant tumor of the innominate bone and upper part of the femur, (2) primary malignant tumor of the soft tissue of the thigh, and (3) recurrent malignant tumor of the upper part of the thigh. Emphasis was placed on the last indications, and examples were presented of patients who had recurrence after limited operations, but who received helpful palliation and possible cure by radical procedure. The importance of performing the radical operation as the first procedure, when indicated, rather than a more limited one, was discussed.

The results of careful follow-up studies of these patients were presented. Four are living without evidence of disease, the longest period of time being eleven years. Of the living patients, two had osteochondrosarcoma of the ilium, one, osteogenic sarcoma of the femur, and one, recurrent liposarcoma of the upper part of the thigh. The average length of survival was fourteen months.

The following helpful measures of aid in the operation were discussed: (1) the position of the patient on the operating table; (2) the technique requiring no turning of the patient; (3)

71. 3720 Washington Boulevard, St. Louis, Missouri.
72. 1020 Kapiolani Street, Honolulu, Hawaii.
73. 3640 Atlantic Avenue, Long Beach, California.
74. 1757 Pacific Avenue, Long Beach, California.
75. Veterans Administration Hospital, Memphis, Tennessee.
76. Veterans Administration Hospital, Portland, Oregon.

the control of the common iliac artery and the veins of the pudendal plexus; and (4) a method for locating the position of the sacro-iliac joint.

A helpful prosthesis to be used during convalescence and a walking prosthesis for patients without local recurrence or metastasis was described.

In discussing this paper, Dr. Donald King[76] pointed out the magnitude of the operative procedure and the indications for its being done. His experience encompasses some twenty-six hemipelvectomies, the last twenty of which were done without death from surgery itself. Technique of the operation was discussed and Dr. King implied that the major portion of the patients reported had been operated upon for malignant disease. Yet he demonstrated the value of this procedure for persistent uncontrolled infection. Dr. King thinks this can be done with perfect safety and will accomplish more for the patient if the procedure is applied early in the disease rather than after dissemination has rendered it a palliative procedure only.

Short Below-Knee Amputations. Dr. Faulkner A. Short[77] presented clinical evidence to indicate that short below-the-knee amputations can yield excellent stumps if they tolerate end-bearing. A cone-shaped stump, recommended in modern textbooks, will not always be the best possible stump. Experience shows that, in below-the-knee stumps less than four inches long, the shape should be cylindrical and the distal end of the stump should be flat or slightly rounded.

The fibula should not be removed except when it is dislocated or when its presence prevents skin closure. The head of the fibula helps to prevent rotation of the stump in the socket.

Scars on the end of the stump tolerate weight-bearing if not tightly adherent to bone. Scars on the sides of the stump cause no trouble if there is end-bearing. Tibial bone easily adapts itself to end-bearing.

Cutting the hamstring tendons gives better function, especially in individuals where the insertions are lower on the stump.

The best prosthesis for end-bearing is a closed end, wood socket with a long thigh lacer. Felt pads are used for heavy bearing and sponge-rubber pads for light bearing. The quadrilaterally shaped wood ischial weight-bearing extension is the next best type of prosthesis if end-bearing is not tolerated.

Epicondylitis (Tennis Elbow). Dr. Roderick E. Begg[78] reviewed the literature, pointed out the etiology of the condition, and discussed the generally accepted pathological findings of tennis elbow (epicondylitis) or radiohumeral bursitis. The author also observed the presence of a prominent ridge on the lateral part of the condyle of the humerus which he termed a gunsight spur. The author outlined his experience with both surgical and conservative treatment. The technique of making roentgenograms which show this spur was described, and a comparison made of roentgenograms of people with symptoms of tennis elbow and those with normal elbows. In reviewing twenty patients with tennis elbow he was able to demonstrate, in approximately one-third of the cases, a typical gunsight spur. The other two-thirds showed no positive roentgenographic findings according to the author's criteria. In the author's experience, the presence of the gunsight spur, when demonstrated, did not appear to alter the results of treatment, either operative or conservative. This coincided with his observation of twenty patients who had roentgenograms made and had no symptoms of epicondylitis and of seven who showed the gunsight spurs. This is approximately equal to the number observed, twenty, in the cases treated.

77. 441 Medical Arts Building, Portland, Oregon.
78. 1922 N.W. Johnson, Portland, Oregon.

CONGRESS OF THE SOCIEDADE BRASILEIRA DE ORTOPEDIA E TRAUMATOLOGIA

As Reported by Dr. F. E. Godoy Moreira, São Paulo, Brazil

The Twelfth Congress of the Sociedade Brasileira de Ortopedia e Traumatologia was held in São Paulo, Brazil, from July 28 through August 2, 1958.

The meetings were held under the auspices of Dr. D. Define, São Paulo, President; Dr. J. B. Sardinha, Rio de Janiero, Vice-President; and Dr. O. Graner, São Paulo, Secretary.

The subjects treated were:

Recurring Dislocation of the Shoulder. (Moderator: Dr. O. Pinto de Souza.) Dr. Walter Barbosa and Dr. D. D'Angelo (Rio de Janiero) recommended operative methods that aim at repair of the lesions found in this condition and said that they were not in favor of those which try to create an obstacle to recurrence of the dislocation.

Treatment of the Fractures of the Pelvis. (Moderator: Dr. D. Chaves.) Dr. O. Rudge (Rio de Janiero) and Dr. L. Mabilde (Porto Alegre) discussed the classification, treatment, and complications of these fractures. They recommended that treatment should be conservative in the great majority of cases. They recommended surgery for those patients with severe pubic or sacro-iliac dislocations and felt that the cooperation of a urologist was indispensable.

Treatment of Congenital Club-Foot. (Moderator: Dr. O. P. Campos.) Dr. W. S. Rosa (Rio de Janiero) and Dr. J. Vicenzo (São Paulo) reported on their treatment in two thousand cases of congenital club-foot.

The Kite procedure was adopted and, when treatment was started early, they found that results were satisfactory in 90 per cent of the cases.

In discussion, Dr. D. Define (São Paulo) described the technique of the Codvilla operation which gives good results where conservative treatment failed. Dr. E. P. Carvalho (São Paulo) recommended transplantation of the extensor hallucis proprius to the fifth metatarsal for the correction of the adduction deformity. Dr. B. C. Carvalho (São Paulo) advised, in resistant or neglected cases, to begin with the Kite method and, after maximum correction has been obtained, to perform triple resection arthrodesis, Achilles-tendon lengthening, posterior capsulotomy, and, in some cases, wire traction to the calcaneus.

Dr. E. P. Souza (São Paulo) described The Club-Foot Clinic of the Pavilhão Fernandinho.

Rehabilitation in Orthopaedic Surgery. Dr. R. C. Bomfim (São Paulo) spoke of the need of cooperation by the government with orthopaedic surgeons to spread the principles of rehabilitation throughout the country.

Brazilian organizations with a rehabilitation program are working in a group effort to spread the principles and benefits of rehabilitation throughout the country.

Treatment of Infantile Paralysis. (Moderator: Dr. L. G. Wertheimer.) Dr. O. P. Campos (Rio de Janiero) and Dr. R. R. Alves (Rio de Janiero) described the techniques employed and results obtained at the Hospital Jesus, especially in the treatment of acute cases of respiratory and deglutive complications.

Additional papers read were:

Laboratorial Tests in the Diagnosis of Infantile Paralysis by Dr. R. A. Moura (São Paulo) and **Diagnosis in the Acute Stage of Infantile Paralysis** by Dr. A. B. Lefèvre (São Paulo).

The following conferences were presented by guest speakers:

Recurring Dislocation of the Shoulder. Dr. Merle D'Aubigné (Paris) stressed the necessity of treating specific lesions found in each patient and described the most characteristic lesions. He recommended the Putti-Platt operation when distension of the capsule is present and the Bankart procedure when there is detachment of the capsule.

Cervical-Disc Herniae. Prof. Oscar Scaglietti (Florence) described the clinical aspects and signs of compression of the sixth and seventh cervical-nerve roots. He found those roots to be the most frequently involved and to give the most characteristic symptoms. In the less common cases of central herniae with cord compression, the speaker advised that myelographic and centrospinal fluid studies be made. A film was shown to demonstrate the operative technique.

Compression Arthrodesis of the Hip Joint. Mr. John Charnley (Manchester) used a series of slides to demonstrate the technique and principles of his operation. He stated that the operative risk is minimal and the technique simple, giving a high percentage of good results. He considered that the results were good even in those patients in whom union did not take place because an adequate and painless gait was accomplished.

Tabic Arthropathy of the Knee Joints. Dr. José Valls discussed the physical, pathological, clinical, and diagnostic aspects of tabic arthropathy as well as the indications for surgery. A description was given of compression arthrodesis—the operation advised. Good results, confirmed by histological studies, were obtained through osseous union.

Fundamentals, Indications, and Techniques of Subtrochanteric Osteotomies. Dr. Carlos E. Ottolenghi (Buenos Aires) discussed subtrochanteric osteotomy in regard to failure of different arthroplasty techniques. If a strict technique is followed subtrochanteric osteotomy will give good results. The author described his technique: he introduced a metal blade into the neck of the femur and attached it to the femoral diaphysis by means of screws.

Rotatory Trauma and Its Implications in the Treatment of Fractures of the Upper Extremity. Dr. José Luis Bado (Montevideo) stressed the importance of rotation in the mechanism of production and in the treatment of fractures of the upper extremity. He discussed the Monteggia lesion, fractures of the forearm, wrist, humerus, and elbow and recommended that in order to reduce these fractures one should employ the opposite movements and forces that produced them.

Treatment of the Paralytic Shoulder. Dr. Oscar Marottoli (Rosario) stressed the necessity of careful study of all muscles involved and the degree of impairment before deciding the operative procedures to be performed; tendon transfer, glenohumeral arthrodesis, scapulodesis, or a combined operation.

The Painful Shoulder—Experience of 2,580 Cases With Special Reference to Calcified Tendinitis. Dr. Paul Harmon (San Francisco) discussed the main causes of painful shoulder including their relative frequency and the treatment recommended in each case.

News Notes

THE AMERICAN ORTHOPAEDIC ASSOCIATION

The Seventy-Second Annual Meeting of The American Orthopaedic Association will be held at the Lake Placid Club, Lake Placid, New York, June 15 to 18, 1959, under the presidency of Dr. C. Leslie Mitchell. The tentative program of the Meeting, as submitted by the Program Committee, is as follows:

Monday, June 15

Morning Session

Interscapular Fascial Transplants. An End-Result Study of Thirty-Two Cases.
J. Vernon Luck, M.D., Los Angeles, California;
Charles LeRoy Lowman, M.D., Los Angeles, California.

An Estimate of Prognosis in Cerebral Palsy.
William Cooper, M.D., New York, N. Y.

Effects of Rotary and Valgus Malpositions on the Blood Supply to the Femoral Head.
Frank B. Smith, M.D., Portland, Oregon.

Surgical Treatment of Brachial Plexus Injuries.
James E. Bateman, M.D., Toronto, Ontario, Canada.

Introduction of the Exchange Fellows.
John P. Adams, M.D., Washington, D. C.;
Sherman S. Coleman, M.D., Salt Lake City, Utah;
Andrew H. Crenshaw, M.D., Memphis, Tennessee;
James S. Miles, M.D., Denver, Colorado.

Executive Session

Evening

The President's Reception.

Tuesday, June 16

Morning Session

The Architecture and Mechanical Strength of the Epiphyseal Line.
Charles O. Bechtol, M.D., Los Angeles, California.

Effects Produced in the Cartilaginous Epiphyseal Plate of Immature Dogs by Experimental Traumata.
Crawford J. Campbell, M.D., Albany, New York;
Andres Grisolia, M.D. (by invitation), Albany, New York;
George Zanconato, M.D. (by invitation), Albany, New York.

An Evaluation of Epiphyseodesis and Treatment of Leg-Length Discrepancy.
Philip D. Wilson, M.D., New York, N. Y.
T. Campbell Thompson, M.D., New York, N. Y.
Lee Ramsay Straub, M.D., New York, N. Y.
Philip A. Granieri, M.D. (by invitation), Boston, Massachusetts.

The Effects of Continuous Compression of Articular Cartilage.
R. B. Salter, M.D., (by invitation), Toronto, Ontario, Canada.

Guest of Honor

Wilfried F. H. M. Mommaerts, Professor of Medicine and Professor of Physiology, University of California, Los Angeles, California.

Evening

Cocktail Party.

Wednesday, June 17

Morning Session

Fibrous Dysplasia: A Twenty-Five Year Study with Follow-Up.
William H. Harris, M.D. (by invitation), Boston, Massachusetts;
Patricia H. Benedict, M.D. (by invitation), Boston, Massachusetts;
H. Robert Dudley, Jr., M.D. (by invitation), Boston, Massachusetts;
Roy Barry, M.D. (by invitation), Boston, Massachusetts.

Electromyographic Study of Transplanted Muscles about the Knee in Poliomyelitic Patients.
David H. Sutherland, M.D. (by invitation), San Francisco, California;

Frederic C. Bost, M.D. (deceased), San Francisco, California;
Edwin R. Schottstaedt, M.D., San Francisco, California.

The Anatomy of Congenital Talipes Equinovarus (with Ten Dissected Specimens).
George W. Settle, M.D. (by invitation), Baltimore, Maryland.

Progressive Changes in Benign Cortical Defects of Long Bones: Radiographic Features.
John Caffey, M.D., New York, N. Y.

Presidential Address.
C. Leslie Mitchell, M.D., Detroit, Michigan.

Evening

Cocktails.
Annual Banquet and Ball.

THURSDAY, JUNE 18

Morning Session

Correlation of the Myelogram to Clinical and Operative Findings in Lumbar Disc Lesions.
Edward Lansche, M.D. (by invitation), St. Louis, Missouri;
Lee T. Ford, M.D., St. Louis, Missouri.

Lumbosacral Disc Disease. The Results of Surgical Treatment.
Beckett Howorth, M.D., Stamford, Connecticut.

The Role of Soft Tissues in Osteogenesis (an Experimental Study of Canine Spine Fusions).
Frank E. Stinchfield, M.D., New York, N. Y.;
Lloyd A. Hurley, M.D. (by invitation), New York, N. Y.;
C. Andrew L. Bassett, M.D. (by invitation), New York, N. Y.

Postirradiation Fractures of the Neck of the Femur.
William H. Bickel, M.D., Rochester, Minnesota.

Second Executive Session.

The Committee on Scientific Investigation of The American Academy of Orthopaedic Surgeons announces that all manuscripts to be entered for the **Kappa Delta Award,** which is presented annually for the outstanding scientific contribution in the field of orthopaedic surgery and which carries an honorarium of $1,000, should be submitted by July 1, 1959. The manuscript should be forwarded to the Chairman of the Committee: Dr. Frank E. Stinchfield, Columbia-Presbyterian Medical Center, 180 Fort Washington Avenue, New York 32, N. Y.

The winner of the Award will be asked to present the paper before the Annual Meeting of The American Academy of Orthopaedic Surgeons in January 1960. It is, therefore, suggested that the manuscripts be submitted as early as possible so that the utmost care may be given in evaluating each contribution.

The Part II examination of the **American Board of Orthopaedic Surgery** for certification will be held January 19, 20, and 21, 1960, in Chicago, Illinois. The deadline for receipt of application is August 15, 1959. Application should be made to Sam W. Banks, M.D., *Secretary,* 116 South Michigan Avenue, Chicago 3, Illinois.

The Sixth Annual Meeting of **The Society of Nuclear Medicine** will be held in Chicago, Illinois, June 18 through 20, 1959. Additional information may be obtained by writing to Samuel N. Turiel, *Administrator,* The Society of Nuclear Medicine, 750 North Michigan Avenue, Chicago 11, Illinois.

The **Association of Bone and Joint Surgeons** will meet in Washington, D. C., April 12 through 15, 1959. Dr. William M. Deyerle, 2222 Monument Avenue, Richmond 20, Virginia, is Secretary.

The Sixth **Congreso Nacional de Ortopedia y Traumatología** will be held in Mexico City from May 2 to May 7, 1960. The general theme of the meeting has been announced as Problems of Articulation. For detailed information write to the President of the Committee on Organization, Dr. Xavier Romo Diez, Calzada de Tacubaya 101, Mexico 11, D. F.

The Seventy-First Annual Meeting of the **American Association of Railway Surgeons** will be held in Chicago, Illinois, April 16, 17, and 18, 1959.

The Third Annual **Post-Graduate Course in Fractures and Other Trauma** of the **Chicago Committee on Trauma of the American College of Surgeons,** April 15 through 18, 1959, Murphy Memorial Auditorium, is dedicated to the memory of Dr. Fremont A. Chandler, former Professor and Head of the Department of Orthopaedic Surgery of the University of Illinois. Members of the Planning Committee for this Course are Dr. John J. Fahey, Dr. Sam W. Banks, Dr. J. D. Farrington, Dr. William A. Larmon, and Dr. Vernon C. Turner.

The **Gordon Research Conference on Chemistry, Physiology, and Structures of Bones and Teeth** will be held July 13 through 17, 1959, at Kimball Union Academy, Meriden, New Hampshire, under the Chairmanship of W. D. Armstrong. The program is as follows:

July 13

Invited Short Communications. Felix Bronner, *Chairman.*
Bone as a Mechanical Tissue. Jonathan Cohen, *Chairman.*
Bone as a Problem in Mechanical Engineering. G. H. Bell.

July 14

The Relation of the Microscopic Structure of Bone to Its Strength Characteristics and Other Physical Properties. F. G. Evans.
Mechanical Properties of Bone from Radium Poisoned Dogs. H. Hollinghaus.
The Transmission of Weight Through the Knee Joint. M. G. Hardinge.
Fluoride Metabolism. Harold C. Hodge, *Chairman.*
Broad Aspects of Fluoride Metabolism. D. A. Greenwood.
Radiofluoride Studies. Yngve Ericsson.

July 15

Bone Retention of Fluoride. P. H. Phillips.
Radiofluoride Distribution in Animals under Chronic Fluoride Exposure. C. S. Hobbs.
Urinary Fluoride Levels in Relation to Change in Osseous Radiopacity. E. J. Largent.
Fluoride Content and the Chemistry of Human Skeletal Tissue. F. J. McClure.
Mechanism of Renal Excretion of Fluoride Determined with Radiofluorine. C. H. Carlson.
Plasma Fluoride Concentrations in Relation to Fluoride Intake. Leon Singer.
New Developments in Methodology in Study of Calcified Tissues. D. Dziewiatkowski, *Chairman.*
Some New Aspects of Ultrastructure of Bone. Diego Carlström.

July 16

Histochemical Changes at Sites of Calcification. James Irving.
High Resolution Microradiography. Richard Greulich.
Quantitative Determination of Bone Mineral Content and Bone Density *In Vivo* from Standardized Roentgenograms. Harold Schraer.
Pathological Physiology of Bone and Calcium Metabolism. Franklin C. McLean, *Chairman.*
Idiopathic Hypercalcaemia. G. Fanconi.

July 17

Studies on Acid Mucopolysaccharides. Albert Dorfman.
Hypophosphatasia. Donald Fraser.
Mechanisms of Mineralization in Molluscs. Karl M. Wilbur.

Requests for attendance at the conference or for additional information should be directed to W. George Parks, *Director,* Department of Chemistry, University of Rhode Island, Kingston. From June 15 to September 4, mail should be addressed to Colby Junior College, New London, New Hampshire.

The 1959 **Kappa Delta Award** for the outstanding contribution in the field of orthopaedic surgery was given to Melvin J. Glimcher, M.D., Department of Biology, Massachusetts Institute of Technology for work entitled Molecular Structure and Biological Specificity in Mineralization. The Kappa Delta Award is made possible by the Sorority with more than eighty college chapters and 235 chartered alumnae associations. The Sorority has been supporting crippled children's programs for several years.

Book Reviews

CONGENITAL ANOMALIES OF THE HAND AND THEIR SURGICAL TREATMENT. Arthur Joseph Barsky, M.D., D.D.S. Springfield, Illinois, Charles C. Thomas, 1958. $5.75.

This monograph in the American Lecture Series in Orthopedic Surgery is based upon the author's series of 165 patients with congenital deformities of the hands and a survey of the literature of the last thirty-five years. Parts of it appeared in The Journal of Bone and Joint Surgery, 33-A: 35-64, Jan. 1951. There are short introductory chapters on incidence and etiology of congenital malformations of the hand with a succinct review of genetics as applied to these deformities. A simple grouping, rather than a complicated classification, is used and each general type occurring in the series is the basis of a chapter showing typical cases, incidence, some references to the literature, and method of treatment.

Utilizing his own experience, the author selects the most common deformity and discusses the incidence, etiology, and treatment. Each type of deformity in descending frequency is thus treated. The discussions are clear and other authors are quoted extensively. The broad principles of treatment, rather than minute details, are listed.

The author's style is relaxed and the book is easy to read. In addition to many illustrations, there is an adequate index and a glossary of terms used in this field.

This book should be of considerable value to obstetricians and pediatricians for it provides the best answers, that we have up to this time, for parents of children with these anomalies.

Joseph H. Boyes, M.D.

THE CERVICAL SYNDROME. Ed. 2. Ruth Jackson, B.A., M.D., F.A.C.S. Springfield, Illinois, Charles C. Thomas, 1958. $6.50.

For many years Ruth Jackson has made an earnest effort to understand better the numerous orthopaedic and neurological entities manifest in the cervical spine. This second edition of her book presents her views and observations as they have evolved from a vast clinical experience. As would be anticipated, she has included a review of pertinent anatomical and physiological material. Many of the clinical symptoms are interpreted upon an anatomical basis. Allocation of pain in cervical-spine entities is truly a complex subject; we are confronted with wide gaps in our knowledge. Dr. Jackson bridges most of these gaps by theories, having for the most part an anatomical basis.

In this second edition, the monograph has forty new illustrations as well as more material on whiplash injuries and more details on the interpretation of roentgenograms of the cervical spine.

Dr. Jackson speaks frequently of nerve-root irritation, but indicates that she means root compression. Whether or not this concept of nerve-root irritation is adequate to explain some of the symptoms attributed to it has to be established.

While the term cervical syndrome is a catch-all to cover most of the entities related to the cervical spine, and in itself means nothing, the author does urge that every effort be made to arrive at an accurate and specific diagnosis. The use of the procaine test of Steindler is recommended as part of the diagnostic survey.

This splendid book is written primarily for clinicians and places in their hands abundant information that can be utilized in terms of decided benefit to the patient. There is an excellent section on therapy, with numerous case studies for illustration.

The physical qualities of the book are superb. This monograph has a place in the library of all physicians who treat cervical spines.

J. Vernon Luck, M.D.

12 NEW BOOKS for Orthopedic Surgeons

✓ New Techniques ✓ Fresh Procedures ✓ Tested Applications

FUNCTIONAL BRACING OF THE UPPER EXTREMITIES: The Rationale, Principles, and Techniques of Upper Extremity Bracing to Prevent Deformities and Restore Function *by* **Miles H. Anderson,** *Univ. California.* The first book ever published in which the subject of upper-extremity bracing is discussed to the extent of giving detailed instructions for fabrication and fitting. *Pub. '58, 480 pp. (8½ x 11), 1057 il., $9.50*

DEGENERATIVE CHANGES IN THE STERNOCLAVICULAR AND ACROMIOCLAVICULAR JOINTS IN VARIOUS DECADES *by* **Anthony F. DePalma,** *Jefferson Med. Coll.* These observations permit the surgeon, internist, and pathologist to place the correct evaluation on the pathological processes encountered and point out the CORRECT METHOD OF MANAGEMENT. *Pub. '57, 184 pp., 196 il., (Amer. Lec. Orthopedic Surgery), $5.50*

ELONGATION TREATMENT OF LOW BACK PAIN *by* **George H. Hassard** *and* **Charles Lambert Redd,** *both of Owens-Illinois Glass Company, Alton, Illinois.* Basic considerations of musculo-fascio-ligamentous disorders are discussed briefly. Then step-by-step illustrated procedures of examining, testing, and treating these enigmas are presented. The scope of application is wider than the title implies, as procedures for treatment of other common soft tissue disorders are incorporated. *To be published April 1959*

CONGENITAL ANOMALIES OF THE HAND AND THEIR SURGICAL TREATMENT *by* **Arthur Joseph Barsky,** *Albert Einstein Coll. of Medicine.* Based on the author's extensive experience in this field but written for the day-to-day use of the busy practitioner. Includes most of the known anomalies of the hand and presents treatment of each condition in step-by-step form. *Pub. '58, 176 pp., 202 il., (Amer. Lec. Orthopedic Surgery), $5.75*

STRESS AND STRAIN IN BONES: Their Relation to Fractures and Osteogenesis *by* **F. Gaynor Evans,** *Wayne Univ.* For the first time in one volume A CRITICAL DISCUSSION of the more important experimental investigations on stress and strain in bones and bony tissue. Emphasis throughout on relation of stress and strain to fractures and fracture healing. *Pub. '57, 264 pp., 96 il. (Amer. Lec. Medical Physics), $6.50*

THE CERVICAL SYNDROME *by* **Ruth Jackson,** *Univ. Texas.* Forty new illustrations taken from the personal examination and treatment of 1,000 more cases of cervical spines add to the usefulness of this new edition. "This valuable book should be useful to the general practitioner, orthopedist, and neurosurgeon."—J.A.M.A. *2nd Ed. pub. Jan. '59, 205 pp., 215 il. (3 in full color), $6.50*

THE HAND: Its Anatomy and Diseases *by* **John J. Byrne,** *Boston Univ.* The broad scope of this book covers all phases of hand disease including structure and development, infections, trauma, diseases, occupational stigmata, and reconstructive surgery. Well annotated with references which are not confined to American sources, but present a review of the available world literature of the past decade. *Pub. Jan. '59, 408 pp., 233 il., $10.50*

THE SURGICAL TREATMENT OF SCOLIOSIS *by* **Louis A. Goldstein,** *Univ. Rochester.* For many years the orthopaedist has sought an authoritarian publication which would give him some of the answers he has been seeking in his care of the scoliotic child. Dr. Goldstein's monograph answers those questions. *(Amer. Lec. Orthopedic Surgery.) To be published May 1959*

HEMOPHILIC ARTHROPATHIES: The Principles and Practice of Orthopaedic Treatment *by* **Henry H. Jordan,** *Lenox Hill Hosp., New York City.* Demonstrating for the first time the techniques for successful rehabilitation in the field of hemophilic arthropathies. Many fine illustrations including x-ray films of hemophilic joints. *Pub. '58, 264 pp. (7 x 10), 64 il., $8.50*

BONE TUMORS: General Aspects and an Analysis of 2,276 Cases *by* **David C. Dahlin,** *Mayo Clinic.* Based on a systematic nine-year review of the clinical, gross pathologic and histopathologic features of 2,276 consecutive primary tumors of bone seen at the Mayo Clinic, this amply illustrated presentation affords a handy reference to salient features of various primary neoplasms of bone. *Pub. '57, 236 pp. (8½ x 11), 353 il., $11.50*

LIGAMENT AND TENDON RELAXATION (Skeletal Disability) TREATED BY PROLOTHERAPY (Fibro-Osseous Proliferation) *by* **George Stuart Hackett,** *Mercy Hosp., Canton, Ohio.* Enables the reader to successfully carry out diagnosis and treatment and provides a background for others to continue further investigation of ligament disability. **3rd Ed.** *pub. '58, 160 pp., 32 il., $6.75*

LECTURES ON THE INTERPRETATION OF PAIN IN ORTHOPEDIC PRACTICE *by* **Arthur Steindler,** *State Univ. of Iowa.* Focuses attention on the pain phenomena of the locomotor system from the diagnostic point of view in order to facilitate earlier diagnosis and more effective management. Each situation documented by a number of clinical cases. *To be published August 1959*

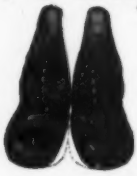
CHARLES C THOMAS • PUBLISHER • 301-327 East Lawrence Avenue • SPRINGFIELD • ILLINOIS

In answering advertisements, please mention *The Journal of Bone and Joint Surgery.*

A MODERN CORRECTIVE SHOE
FOR EVERY *Orthopedic* NEED

TARSO SUPINATOR®

For the postural correction of flat feet.



TARSO PRONATOR®

For club feet and metatarsus varus. Pairs or single shoes.

TARSO MEDIUS®

Straight, neutral last shoe. Detailed to match Tarso Pronator. Pairs or single shoes.

Tarso shoes are fitted on prescription at better shoe stores. Write for nearest dealer or use your regular supplier. Brochure on request.

M. J. MARKELL SHOE COMPANY, INC.
332 S. Broadway, Yonkers, N. Y

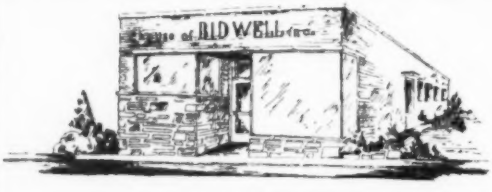
The Ruth Jackson Cervical Collar

of "CERVICAL SYNDROME"
BY
RUTH JACKSON, M.D., F.A.C.S.

An all-purpose plastic collar for extension, stabilization, and the recommended flexed, or straight neck and "chin tucked in", position indicated in whiplash sprains and other cervical conditions. Completely adjustable for proper fitting, position and support with minimal pressure at the ridge of the trapezius. Available to brace makers.

Literature and reprint on request

FLORIDA MANUFACTURING CORPORATION
TERRY MOORE, PRESIDENT
BOX 449 • DAYTONA BEACH, FLORIDA



To serve your complete needs in
ORTHOPEDIC, PROSTHETIC
and SURGICAL APPLIANCES

house of BIDWELL inc.

535 N. 27th Street
Milwaukee 8, Wis.

1134 Regent St.
Madison, Wisconsin

Rely on original Küntscher

CLOVERLEAF medullary NAILS

by Orthopedic

Nails are formed by

C-O-L-D D-R-A-W-I-N-G

for higher proven tensile strength

(not stamped on punch press; not rolled)

Nails are formed by cold-drawing for higher proven tensile strength—not fabricated or stamped on punch press, or rolled. Nail has rounded cusp; no sharp bends or angle points which could cause fracture of the metal. Incidents of Küntscher Nail failure due to breakage are unknown to our customers because of qualitative design and reliability in manufacturing. SMo original Küntscher Cloverleaf medullary nails, instruments and fracture equipment by Orthopedic are available at NO additional cost to the consumer through our company's qualified surgical dealers.

Küntscher
CLOVERLEAF NAILS
All diameters and lengths in stock for immediate delivery.

Write for complete 160-page catalog

Plants in Great Britain and Germany

Orthopedic EQUIPMENT CO.
BOURBON, INDIANA
SPLINTS • FRACTURE EQUIPMENT • SMo INTERNAL BONE APPLIANCES • BONE INSTRUMENTS

FOR TREATMENT OF SPASTIC CASES • CEREBRAL PALSY • STROKE • POLIO • HAND INJURIES

General Electric Co. Silicone

BOUNCING PUTTY

As a "trial order" send $2.00 for one $2.85 jar

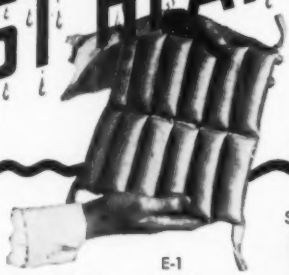
does not harden
lasts indefinitely
and can be
autoclaved.

S. R. GITTENS, *Distributor,* 1620 Callowhill St., Phila. 30, Pa.

HYDROCOLLATOR

Steam PACK

MOIST HEAT



Now moist heat can be applied conveniently, effectively and with a minimum investment in equipment. No dripping, no wringing, no repeated applications. Each application gives at least 30 minutes effective moist heat. The Steam Pack is merely heated in water, wrapped in a towel, and applied. Standard equipment in leading hospitals and clinics across the nation.

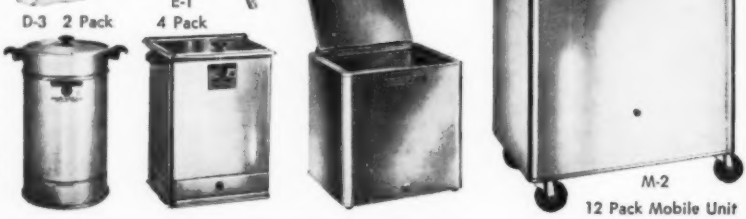
DESCRIPTIVE MATERIAL ON REQUEST

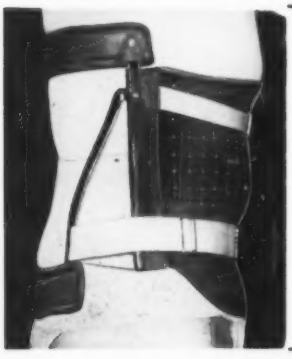
CHATTANOOGA PHARMACAL CO., INC.

CHATTANOOGA 5, TENNESSEE

MASTER UNITS

Four all stainless steel models to meet the various requirements in hospitals, clinics, physicians' offices, and patients' homes. Automatically maintains Steam Packs in water at proper temperature — constantly ready for immediate use. No plumbing used.





WILLIAMS LUMBO-SACRAL FLEXION BRACE

Orders filled at the request of members of the profession only

Measurements: 1. Chest (about 4" below nipple line); 2. Waist (at navel line); 3. Pelvic (½ distance between greater trochanter and crest of ilium); 4. Seventh cervical spinous process to the prominence of Coccyx.

ALL ORTHOPAEDIC APPLIANCES

MILLER BRACE CO.

3902 Gaston Avenue Dallas, Texas

For prompt service use our P. O. Box 7902

Custom Built: Braces—Surgical Supports—Splints—Arch Supports—Folding Wheel Chairs—Aluminum Adjustable Crutches—Airfoam Head Halter Sets—Airfoam Rib Binders—Canes, Etc.

Stryker

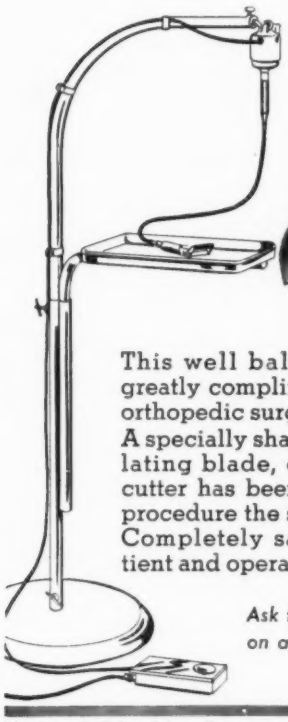
ELECTRO-SURGICAL UNIT

Effective • Safe • Efficient

The Stryker Electro Surgical Unit is becoming standard hospital equipment to accommodate the increasing use of attachable surgical instruments.

The speed and power of the enclosed motor is controlled by the new explosion proof foot switch. The motor may be suspended from an IV stand or from the standard shown below. Each interchangeable instrument is light, sensitive and powered thru a single flexible cable. This variety of tools at the surgeon's finger tips allows versatility and adds artistry to his surgical skill.

Complete unit fits conveniently in a single foam rubber lined carrying case.



BONE SAW

This well balanced hand piece greatly compliments the skill of the orthopedic surgeon in cutting bone. A specially shaped high speed oscillating blade, chisel or bone-plug cutter has been designed for every procedure the surgeon will perform. Completely safe for surgeon, patient and operating room, personnel.

Ask for the Stryker Bone Saw on approval—write today.

Bone Saw
$90.00

Rolo-Dermatome
$148.00

Pencil-Grip Rotary Handpiece
$75.00

Sagittal Plane Saw

The Bone Drill Handpiece Operates each of these tools:

Automatic Screw Driver
$24.50

Bone Drill Head
$110.00

Color-Guide Drill
$28.00

Jacobs Chuck
$15.00

Color-Guide Screw Case
$25.00

Stryker SURGICAL AND HOSPITAL EQUIPMENT

Orthopedic Frame Company

420 ALCOTT STREET • KALAMAZOO, MICHIGAN

Distributed in Canada by: Fisher & Burpe, Ltd., Winnipeg Exclusive Agent for Export: Schueler & Co., 75 Cliff St., N. Y.

TO ORDER *Frejka*

ABDUCTION PILLOW SPLINTS

with the new Wet-Proof pillow

3 SIZES:

Small—6" pillow splint (up to 3 months)
Medium—9" pillow splint (3 to 6 months)
Large—12" pillow splint (over 6 months)

COLORS: Pink, Yellow, or White

Phone—Midway 4-6874

MINNESOTA ORTHOPEDIC SERVICES
1963 Carl Street St. Paul 13, Minn.

PRICES

with one halter $7.75
with two halters $12.50

POSTPAID

KASTOFF®

the modern method for removing casts!

KASTOFF . . . the new way to remove casts quickly, painlessly, safely. NOW . . . with the KASTOFF method even your technician can easily remove casts of the hardest materials without producing the fear, cuts, or burns among your patients of old fashioned cast removal methods.

KASTOFF comes complete with turning clips and one dozen wires at $27.00, with additional wires and clips for $9.50 per dozen. Write for illustrated booklet outlining the use of KASTOFF. Names of successful users of KASTOFF will be furnished upon request.

Call your surgical supply man or write:

KASTOFF
P. O. BOX 8782, DALLAS 16, TEXAS

★ QUICKLY
★ ECONOMICALLY
★ EASILY
★ PAINLESSLY
★ SAFELY

Use Kastoff on your next cast. You and your patient will be glad you did.

PRICE COMPLETE $27.00
WIRES PER DOZEN 9.50

PAT. NO. 2253040

THE UNITED LIMB AND BRACE CO., INC.
15 BERKELEY STREET BOSTON 16, MASSACHUSETTS
Telephone: HAncock 6-4018

Manufacturers of

Artificial Limbs

← This shows how the **Soft Back Rubber Cushion Socket** conforms to the stump when the patient is sitting down

The Journal
takes
Another Step
Forward
in its
71st Year

• • •

The Steps

• • •

1889–1902
An Annual
(The Transactions)

•

1903–1915
A Quarterly

•

1916–1918
A Monthly

•

1919–1947
A Quarterly

•

First British
volume 1948

•

1948–1953
Eight Issues
Four American
Four British

•

1954–1958
Ten Issues
Six American
Four British

•

1959
A MONTHLY

EIGHT
American Issues

FOUR
British Issues

In 1959

THE AMERICAN VOLUME

of

The Journal of Bone and Joint Surgery

will be published

Eight Times a Year

instead of six times as in 1954–1958

There will be no increase in subscription price for the two additional issues.

1959 American Volume • 8 issues $14.50

January	July
March	September
April	October
June	December

The British Volume will continue to be published four times a year

1959 British Volume • 4 issues $7.50

February
May
August
November

Subscriptions and Renewals to Both Volumes may be sent either to

Boston *or* London

The Journal of Bone and Joint Surgery 8 The Fenway Boston, Massachusetts	The British Society of Bone and Joint Surgery 82 Portland Place London W.1, England
American Volume $14.50 British Volume $ 7.50	American Volume £5.4.0 British Volume £2.13.6

PRESTON *A Complete Line* FOR PHYSICAL THERAPY AND REHABILITATION

REHABILITATION: Bicycle Exercisers; Restorator; Walking Parallel Bars and Exercise Staircases of various designs; Posture Mirrors; Gymnasium Mats; Shoulder Wheels with or without height adjustment; Elgin Progressive Resistance Exercise Units; Quadriceps Boots; Dumbbells; Chest Pulley Weights; Standing (Tilt) Tables; Stryker Turning Frames.

HAND THERAPY DEVICES: Kanavel Table; Manuflex; Wrist Exercisers; Complete Line of Bunnell Splints; Theraplast.

TRACTION: Many types of Cervical and Pelvic Traction Sets; Hausted Tractionaid.

HYDROTHERAPY — ELECTROTHERAPY: Whirlpools; Paraffin Baths; Hydrocollator; Ries Moistaire; Medcolator and other Low-Volt Generators; Infrared Lamps; Bakers; Birtcher Ultrasonic Generators.

Everest & Jennings Wheelchairs; Commodes; Walkers and Walking Aids for every need; Hydraulic Patient Lifters; Largest selection of Treatment Tables.

Complete Line of Cerebral Palsy Equipment — Speech Therapy — Self Help Devices for the Handicapped.

THE PRESTON CATALOG #1058

- Features *today's most complete line* of Equipment for Physical Therapy and Rehabilitation
- Lists over 1500 articles, including many new developments
- Your one dependable guide in ordering Physical Therapy Equipment

SEND FOR YOUR FREE COPY TODAY

We supply *ALL EQUIPMENT* for setting up a complete Rehabilitation Program. Suggested layouts and equipment lists are available to you through *OUR FREE PLANNING SERVICE.*

J. A. PRESTON CORP., 175 FIFTH AVENUE, NEW YORK 10, N. Y.

New Comfort for Arthritic Patients!

KLEISTONE'S NEW Lynco #57 CUSHION MOLD

Made of resilient cellular rubber, covered on top with soft, pliable leather. The bottom is not covered, so that this cushion may be altered easily, by additions or reductions to fit the individual case.

Write for full details

KLEISTONE RUBBER COMPANY, Inc.
Established 1919
Warren, Rhode Island, U. S. A.

ORTHOPEDIC POCKET KNIFE

DEVELOPED BY AN ORTHOPEDIC SURGEON FOR ORTHOPEDIC SURGEONS

Special Features

1) Specially constructed curved blade to cut plaster casts.
2) Pry bar for cast spreading and screw driver tip *(fits standard and cruciate heads)*
3) Leather pouch with small sharpening stone.
4) Cuts felt with ease.
5) Always in your pocket for immediate use.

Prices:

Knife, Stone, & Pouch	$ 6.00	5 for	$25.00
Knife only	4.00	4 for	15.00

ORTHOPEDIC POCKET KNIFE
P.O. BOX 224 • CLARK MILLS, N. Y.

NOW READY

To Enable You to Find Quickly
All Journal Papers on Any Subject
Published in the Past Ten Years
In Either the American or British Volumes

THE SUBJECT BIBLIOGRAPHY

1948-1957

of

The Journal of Bone and Joint Surgery

Four main sections, ANATOMY, DISEASE, TREATMENT, RESEARCH.

Six hundred and ninety-nine subject classifications.

Extensive cross-references. For example, a paper on *tendon transfer in the paralysed hand* will be found in the ANATOMY section under HAND, in the DISEASE section under PARALYSIS, and in the TREATMENT section under TENDON TRANSFER.

Author index.

Every listing gives entire title of the paper, authors' names, volume, pages, month and year, and, where necessary, information defining the scope of the paper. Listings on each subject are in chronological order.

The SUBJECT BIBLIOGRAPHY is uniform in size and binding with an issue of *The Journal*.

Price $6.00 through Boston

or

£2.3.0 through London

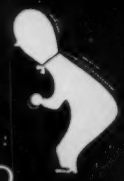
The Journal of Bone and Joint Surgery
8 The Fenway
Boston, Massachusetts

The British Society of Bone and Joint Surgery
82 Portland Place
London W.1, England

in Parkinsonism

"HIGHLY SELECTIVE ACTION"

Disipal®*



Brand of Orphenadrine HCl

"...effective as a euphoriant...and as an energizing agent against weakness, fatigue, adynamia and akinesia... potent action against sialorrhea, diaphoresis, oculogyria, and blepharospasm...also lessens rigidity and tremor... minimal side reactions...safe...even in cases complicated by glaucoma."

Doshay, L. J., and Constable, K.: J.A.M.A. *163*:1352 (Apr. 13) 1957.

*Trademark of Bracadon Shipoman & Pharmaco. U.S. Patent No. 2,567,351. Other patents pending.

Riker

Northridge, California

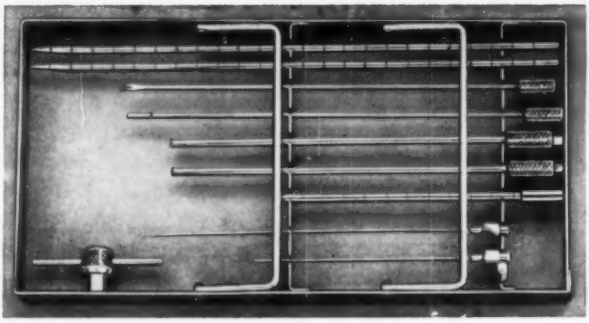
FROM V. MUELLER

Improved Instruments for Vertebral-Body Biopsy

By Frederick S. Craig, M.D., New York. These instruments have resulted in a high percentage of successful biopsies in sclerotic or softened bone, in discs, and in fibrous tissues.

Set Includes:

Calibrated protecting cannula, 11.5 cm. long. Two toothed cutters, used within cannula. 22- and 20-gauge exploring and infiltration needles. Calibrated, semi-blunt trocar to push aside nerve trunks, vessels and other tissues, and to guide cannula. Blunt stylet. Sharp worm hook to remove cut section as cutter is withdrawn.



Reference: The Journal of Bone & Joint Surgery, Volume 33-A, No. 1; page 93 et al., January, 1956. As described in Armamentarium, Vol. II, No. VI.

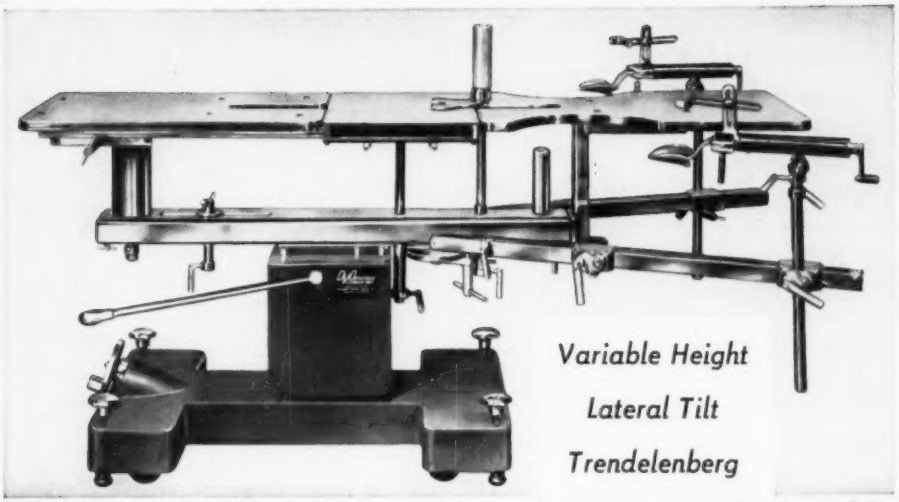
OS-5000 — Craig Vertebral-Body Biopsy Set, complete.....$65.85

V MUELLER & CO.

Fine Surgical Instruments and Hospital Equipment

330 S. Honore St., Chicago 12, Ill. • Dallas • Houston • Los Angeles • Rochester, Minn.

Armamentarium



NEW Model DVHI DV Orthopedic and Surgical Table

Introduced at the Orthopedic Academy Meeting

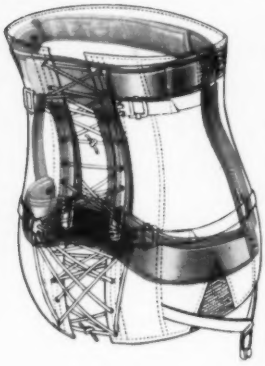
Write to us

GILBERT HYDE CHICK COMPANY

Main Office and Factory — 821-75th AVENUE, OAKLAND 21, CALIFORNIA

In Canada: J. F. Hartz Co., Ltd., Toronto

NEW! *A New Concept in* **BRACE FITTING** *for men and women*



YOU CAN ALSO STOCK SPINAL BRACES IN SIZES NOW.

SEND FOR BROCHURE, FITTING CHARTS and PRICE LISTS.

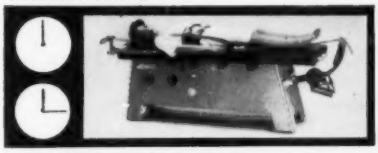
Alexander

INDUSTRIES, INC.

373 EAST BROAD ST., DEPT. 12, COLUMBUS 15, OHIO

PROFESSIONAL TIME IS PRECIOUS . . .

and Hill Traction enables you to utilize every valuable moment.



With the unique gliding top in motion, each articulation is treated separately and evenly by Hill Traction's *exclusive* semi-pneumatic spring-cushioned rollers. The steady rhythm prepares the soft tissue . . . relaxes the patient for the prescribed period . . . allows you to concentrate on more specific problems.

Hill Traction fulfills, *automatically*, the important functions of manipulation, stretching and rolling traction with heat and vibration. You can also use Hill Traction as a multi-purpose treatment table.

For complete information about how Hill Traction helps organize your busy schedule, write today.

HILL LABORATORIES CO.

MALVERN, PENNSYLVANIA

List of Advertisers

APRIL 1959

	PAGE
Aireloom Bedding Company	8
C. H. Alden Shoe Company	44
Alexander Industries, Inc.	67
American Sterilizer Company	45
Austenal, Inc.	9, 10, 11, 12
Bauer & Black, Division of the Kendall Company	4, 5
Becton, Dickinson and Company	47
The Berivon Company	14, 15
Bowen & Company, Inc.	50
S. H. Camp and Company	26
Chattanooga Pharmacal Company	60
G. W. Chesbrough Co.	21
Chesebrough-Pond's, Inc., Professional Products Division	13
Gilbert Hyde Chick Company	67
Codman & Shurtleff, Inc.	30
DePuy Manufacturing Company, Inc.	35
Eastman Kodak Company	17
J. Edwards Shoe Company	20
Elgin Exercise Appliance Co.	69
Fillauer Surgical Supplies, Inc.	25
Florida Brace Corporation	7
Florida Manufacturing Corporation	58
Freeman Manufacturing Company	51
General Electric Co. X-Ray Dept.	32
S. R. Gittens	60
J. E. Hanger, Inc.	49
Herbst Shoe Manufacturing Company	34
Hill Laboratories Company	67
House of Bidwell, Inc.	58
Johnson & Johnson	53, 54, 55, 56
Kastoff Company	62
Kleistone Rubber Company	64
LaBerne Manufacturing Company	42
Lederle Laboratories, Division of American Cyanamid Company	36, 37
McNeil Laboratories, Inc.	27
M. J. Markell Shoe Company, Inc.	58
Medic Shoe Manufacturers, Inc.	41
Medical Research Specialties	28
Merck Sharp & Dohme, Division of Merck & Co., Inc.	43
Miller Brace Co.	60
Minnesota Orthopedic Services	62
V. Mueller & Co.	65
Orthopedic Equipment Co.	59
Orthopedic Frame Company	46, 61
Orthopedic Pocket Knife	64
J. A. Preston Corp.	64
Richards Manufacturing Company	18, 19
Riker Laboratories, Inc.	65
C. J. Robinson	69
I. Sabel, Inc.	52
Chas. A. Schmidt Surgical Instrument Company	24
Simmons Company	16
Smith Kline & French Laboratories	33
E. R. Squibb & Sons	40
Tailby-Nason Co.	6
Charles C. Thomas	57
Truform Anatomical Supports	48
The United Limb and Brace Co., Inc.	62
Wallace Laboratories	31
H. Weniger	69
Winthrop Laboratories	29
Wright Manufacturing Company	38
Wyeth Laboratories	39
Zimmer Manufacturing Company	22, 23

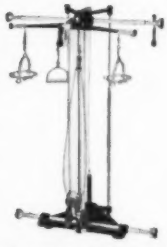
Elgin PROGRESSIVE RESISTANCE EXERCISE EQUIPMENT

Elgin Exercise Unit Model No. A-1500

. . . especially designed for the administration of over 100 therapeutic exercises!

It has been proven that exercise therapy must be accurately controlled if the desired end results are to be obtained . . . Elgin, the original designers and manufacturers of Progressive Resistance Equipment, offers the only complete line of exercise equipment designed to meet these requirements. The Elgin line has been developed, in a scientific manner, to give Doctors and Therapists the correct clinical tools with which to properly administer exercise therapy to both surgical and non-surgical patients.

It provides a wide exercise range, from simple functional exercises to the most highly definitive focal exercises. This equipment also provides a means for an effective and efficient out-patient clinic for patients requiring therapy. An Elgin sales consultant would appreciate the opportunity of assisting you in planning for the inclusion of Progressive Resistance Exercise Equipment in your physical therapy department. Write today for complete information.



ELGIN EXERCISE UNIT
Model No. AB-150

ELGIN LEG EXERCISE
(Ankle) Model No. LE-125

Write today for information on the complete line of Elgin Exercise Accessory Equipment and Therapy Techniques, request Catalog 200.

Elgin EXERCISE APPLIANCE CO.

P. O. BOX 132 • ELGIN, ILLINOIS

Robinson Portable Neck Traction Unit

To be used under the mattress of a single or twin bed.

Light • Strong

Angle of elevation and angle of traction both easily adjusted.

For details and price please write

C. J. ROBINSON
West Swanzey,
New Hampshire.

ACTIVE HAND and FINGER SPLINTS

Instruments for Hand Surgery and Treatment

AS DESIGNED BY

Dr. STERLING BUNNELL

Carried in stock for immediate delivery

- Knuckle bender splint
- Radial palsy splint
- Finger extension splint, etc.
- Hand Drill w/Jacobs chuck
- Tendon stripper set
- Gig pull-out suture and

other special instruments for bone and joint surgery

▶ *Write for catalogue — postage prepaid* ◀

H. WENIGER

Established 1907

New Address

70-12th Street, San Francisco 3, Cal.

ADDRESSES OF CONTRIBUTORS
APRIL 1959

William R. Abbott, M.D., 2065 Adelbert Road, Cleveland 6, Ohio

Walter D. Block, Ph.D., Department of Dermatology and Syphilology, University of Michigan, Ann Arbor, Michigan

Johanna Blumel, Ph.D., University of Texas Medical Branch, Galveston, Texas

Charles R. Booth, M.D., Veterans Administration Hospital, Long Beach, California

Joseph Edmund Brown, M.D., 10515 Carnegie Avenue, Cleveland 6, Ohio

Jonathan Cohen, M.D., 300 Longwood Avenue, Boston 15, Massachusetts

Lawrence Crane, M.D., 265 Western Promenade, Portland 4, Maine

G. W. N. Eggers, M.D., 2201 Avenue D, Galveston, Texas

William F. Enneking, M.D., University of Mississippi Medical Center, Jackson, Mississippi

E. Burke Evans, M.D., University of Texas Medical Branch, Galveston, Texas

Harold F. Falls, M.D., Department of Ophthalmic Surgery, University of Michigan, Ann Arbor, Michigan

Avrum Gratch, B.Sc., Department of Orthopaedics, University of Chicago, 950 East 59th Street, Chicago, Illinois

Mary A. Grebner, B.A., Children's Hospital, 125 DeSoto Street, Pittsburgh 13, Pennsylvania

Richard H. Hall, M.D., Veterans Administration Hospital, Long Beach, California

George Hammond, M.D., 605 Commonwealth Avenue, Boston 15, Massachusetts

Kingsbury G. Heiple, M.D., 2065 Adelbert Road, Cleveland 6, Ohio

Cline D. Hensley, Jr., M.D., The Wichita Clinic, 3244 East Douglas, Wichita, Kansas

Charles H. Herndon, M.D., 2065 Adelbert Road, Cleveland 6, Ohio

Clarence H. Heyman, M.D., 2676 Berkshire Road, Cleveland Heights 6, Ohio

John F. Holt, M.D., Department of Radiology, University of Michigan, Ann Arbor, Michigan

Edgar A. Kahn, M.D., 1313 East Ann Street, Ann Arbor, Michigan

Harvey Kreiger, M.D., 2020 E. 93rd Street, Cleveland 6, Ohio

P. G. Laing, M.B., F.R.C.S., Veterans Administration Hospital, University Drive, Pittsburgh, Pennsylvania

G. N. Lassar, M.D., Pine Lawn Medical Center, 6223 Natural Bridge Road, St. Louis, Missouri

Stanley Levey, Ph.D., 2065 Adelbert Road, Cleveland 6, Ohio

Laverne R. Madancy, B.S., Children's Hospital, 125 DeSoto Street, Pittsburgh 13, Pennsylvania

Robert Mazet, Jr., M.D., Veterans Administration Hospital, Los Angeles 25, California

H. Relton McCarroll, M.D., 3720 Washington Boulevard, St. Louis, Missouri

Winthrop M. Phelps, M.D., 3038 St. Paul Street, Baltimore 18, Maryland

John G. Rukavina, M.D., 749 Lowry Medical Arts Building, St. Paul, Minnesota

Richard C. Schneider, M.D., 1313 East Ann Street, Ann Arbor, Michigan

George E. Spencer, Jr., M.D., 2065 Adelbert Road, Cleveland 6, Ohio

Marshall R. Urist, M.D., 1019 Gayley Avenue, Los Angeles 24, California

Melvin Brent Watkins, M.D., 180 Fort Washington Avenue, New York 32, N. Y.

S. L. Weissman, M.D., 120 Achad Haam Street, Tel-Aviv, Israel

RUMFORD PRESS
CONCORD, N. H.